RECENT DEVELOPMENTS IN THE USE OF PRESSES AND PRESS TOOLS.

Paper presented to the Institution, Glasgow Section, by N. C. Wilson.

WITHOUT machinery we should still be living in a primitive state and should be doomed to an existence which would be only a succession of menial tasks which would occupy us for most of our waking hours. The invention of machine tools of all kinds has arisen from the ever present urge in man to think of a means of transferring the load from his shoulders on to some kind of mechanical device which could bear the burden without fatigue. This urge to invent and improve has resulted in the steady growth of the science of engineering. The beginnings of this science are not easy to trace as there is no reliable record of events prior to 700 B.C., when the Greeks who had migrated to Ionia began to develop their primitive arts and crafts.

The work of this little group of pioneers influenced the successive civilisations of Greece and Rome, but no notable advance was made until Friar Bacon, who was born in the year 1214, began his work. To him is ascribed the invention of gunpowder and the discovery of the principle of the telescope. His contemporaries looked upon him as an alchemist and a sorcerer and it was not until modern times that his work was rightly appreciated. He might truly be described as one of the " early fathers of engineering science."

Birth of the Modern Factory System.

The period of the Renaissance, which commenced in the 14th century, brought the invention of printing and the discovery of America. The effect of these epoch-making events spread in the 16th century to Northern Europe, and the work of such giants as Galileo, Newton, Arkwright, and Watt is too well known to need more than passing mention. The inventions of Arkwright, and Watt, and their disciples, gave birth to the modern factory system which in its turn might be described as the characteristic feature of the industrial revolution. The great cost of these machines and also the necessity for erecting a suitable workshop in which to house them intensified the system of capitalist control which had begun to emerge half a century earlier. Whatever the results have been, and they have sometimes been good and sometimes bad, it should

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at least be conceded that there was a vast enlargement and cheapening of production and a consequent improvement in the standard of living. This time marks the commencement of the problem which surrounds us in an intensified form to-day. It is instructive to read in the daily press that the report of the U.S. Research Committee on Social Trends says, after three years of investigation, that there must be either a speeding-up of social invention or a slowing down of mechanical invention or else grave maladjustments are certain to result. Technological unemployment—unemployment due to the increased efficiency and use of the machine, is the most complex problem confronting us to-day.

A machine is not an inert mass—it is a vital, throbbing, moving thing, if only it is maintained. Indeed, the only incentive it needs in order to render untiring and reliable service is proper maintenance. Its service is not affected by the fear of discharge, and its efforts are not increased by the promise of a rise in wages. This obedient slave will do its master's bidding without any wish to change its work. Men thirst for variety, but presses have a passion for

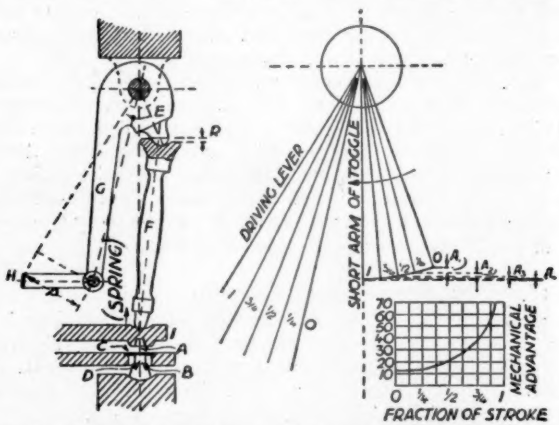

Fig. 1.—Demonstrating Mechanical Advantage of Toggle Mechanism.

uniformity and an endless capacity for monotonous repetition which is only limited by the hours of the day. If any of this capacity is not used it is lost for ever, because, unlike its creator, the machine cannot fill in its time with hobbies and side-lines, hence the urgent need to tend it faithfully, as its birthright is limited to one capacity, and this inheritance prescribes every act of its life.

In no branch of the machine tool trade have greater strides been made than in the press and press tool section. Here is an instrument

which has made it possible to produce at great speeds articles of intricate shapes in sheet metal and other materials which formerly were made, if at all, by craftsmen with primitive hand tools.

The earliest form of press—the screw press—was used in the process of coining and was introduced by the celebrated artist Benvenuto Cellini in the middle of the 16th century. Before that date little or no improvement had been made in the art of coining from the time of its invention. The metal was simply hammered into strips which were afterwards cut into squares of one size and then forged round. The required impression was given to these by placing them between two dies and striking them with a hammer. As it was not easy by this method to place the dies exactly above each other, or to apply the proper force, coins so made were always faulty, and had the edges unfinished, which rendered them liable to be clipped.

Modern Coining Presses.

In recent years great strides have been made with this process and the modern coining press fitted with its automatic feeding attachment is probably a greater advance on the screw press than the latter was on the original method of production. Although this particular press could not be described as the most popular type, it is nevertheless frequently used nowadays for other operations than that of minting coins, especially for cold pressing operations.

In view of the heavy nature of the work of minting which these

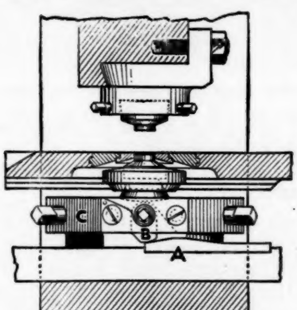

Fig. 2.—Diagram showing Coining Press Dies and details of Patented Extractor.

machines perform, the frames are cast in one piece, a feature which ensures that the moving parts work accurately, and they are of robust design. The pressure is exerted by means of a system of toggle levers, which are operated by a crankshaft at the back of

the press. The revolution of the crankshaft, on which the flywheel is mounted, actuates the toggle lever which transmits the pressure to the dies. The toggle steelings are in holders and renewable.

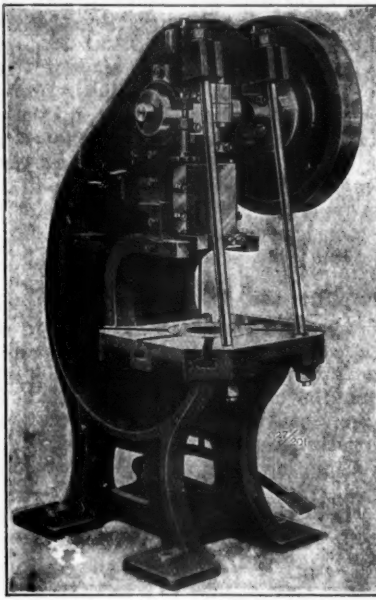

Fig. 3.—Typical Single-acting Press.

They are hardened and ground and of ample surface to withstand the pressure without overheating.

Toggle Mechanism.

It is a well-known property of the toggle mechanism that the mechanical advantage increases, at first slowly, but then very rapidly indeed as the two parts come into line. This is demonstrated clearly in Fig. 1. Here the stroke of the driving lever g has been divided into four equal parts. It is seen that a movement a, is imparted to the die during the first quarter of the stroke, i.e., from 0 to $\frac{1}{4}$, whereas, for the same distance traversed by the end of the lever g during the last quarter, i.e., from $\frac{3}{4}$ to 1, the movement of the tool is reduced to the exceedingly small amount a_4.

The resulting increase in mechanical advantage is shown in the plotted curve in the same Fig. Top and bottom wedge adjustments

are provided for imparting the requisite amount of vertical movement to the tools for setting purposes.

Improvements in Coining Presses.

It is possible only to refer briefly to the many interesting devices which are incorporated in these minting machines. The blanks to be coined are thrown in the automatic hopper, which delivers them to the feeding fingers, which in turn deposit them inside the collar surrounding the bottom tool. The slide now descends and the obverse and reverse designs are embossed on the blanks and, when required, the milling or lettering round the edges of the coins is pressed in at the same time.

This is made possible by reason of the fact that both the top and bottom tools enter the collar for a short distance before the pressure is applied. The metal, being thus prevented from flowing outwards in a radial direction, retains its circular form and is constrained to fill up the smallest depressions in the dies and a sharp impression results. (Fig. 2). The slides of these machines are counter-balanced to eliminate backlash and volute springs are fitted to carry the weight of the top chock of the main toggle gear.

A slight circular movement is imparted to the bottom die, which has the effect of sharpening the impressions to a greater degree than is possible with a simple vertical blow only. The bottom tool is mounted on a rotule, which allows adjustment to the die-face level to equalise the impression over the coin. Formerly, these machines could not be operated at more than 80 to 100 revolutions per minute, but a recent improvement, which renders the bottom ejector operative in the forward direction only, enables them to be run at as many as 135 strokes per minute.

This improvement consists in the substitution of a pivoted pawl on the ejector gear, for what was formerly a fixed projection, which caused a second lift of the bottom die on its return stroke. The double lift of the ejector is liable to cause a displacement of the blanks when the machine is run at high speeds.

Types of Presses.

There are two distinct types of mechanical presses in general use for the production of the vast majority of articles made from sheet metal, namely :

(1) *Single-acting* (Fig. 3) having only one slide which is driven by crank and connecting rod motion from the main shaft of the machine ; and (2) *Double-acting presses*, having an inner and an outer slide. The inner slide is actuated by crank mechanism, as in the case of a single-action type, and the outer slide either by cams in the case of the smaller sizes, or by toggle gear in the case of the larger sizes.

There is another class known as *triple-action presses*, which are provided with an additional movement to enable two drawing processes to be done at one revolution of the crankshaft. This type is only in general use in the hollow-ware trade and is really only a special form of the double-action press, but for certain work it is very effective and enables some of the annealing operations to be cut out.

Again, there are *power-driven screw presses*, which are actuated by means of two friction discs acting on the rim of a flywheel keyed horizontally on the top of the screw. The rim of the flywheel is covered by a suitable type of leather band. These are really a special form of single-action press. Finally, there are brake presses for bending sheets and multiple punching operations.

The class known as single-action presses is made in several forms, the chief of which are :

(1) *Open Throat type* (*a*) with flywheel at side, and (*b*) with flywheel at back ; (2) *Double-sided, single-crank presses ;* (3) *Double-crank presses* ; and (4) *Horizontal presses.*

The smaller range of single-action presses known as open-throat machines are usually made up to a capacity of 75 to 80 tons pressure. This type, which is well known, is used for a wide range of blanking, piercing, small cutting and cupping, forming, and bending operations.

These machines are often fitted with special forms of automatic feeding attachments of which the most popular are : (1) Double or single roller feed motion, which can be operated, if necessary, at high speeds, up to 400 revolutions per minute ; (2) slide feed attachments ; (3) turntable feeds. These machines are now provided with a quick feed and long dwell to the carrier plate, enabling 230 degrees of stroke of the crankshaft to be usefully employed ; and (4) gripper feeds.

It is common practice nowadays to fit an adjustable stroke connecting rod to these machines without automatic feeds. The object of this feature is to be able to arrange the stroke to suit the conditions of the job in question. Blanking operations call for short strokes and bending and cutting and raising processes require longer strokes. The larger sizes of these single-action presses are usually made with *double-sided frames* as shown in Fig. 4. They are provided with either one or two cranks according to the area of the operations to be performed.

Formerly these machines were made with cast-steel or cast-iron frames, on one piece, but a recent fundamental alteration in their design has been effected in that the frames are now built up with loose sides which are registered into the crown and base, and securely held together by four massive steel tie rods, which are shrunk into place. The four tie rods take the pressure strains and

the side frames are of ample section to withstand any lateral stresses which might occur when the slide is unevenly loaded.

Modern Trend.

The present trend in presswork is in the direction of larger pieces, such as motor-car, refrigerator, gas-cooker, and similar work, as compared with hollow-ware domestic utensils which formerly were the largest type of sheet-metal operations in general use. This extension of the application of presses to larger and more varied work has brought into being machines with adequate tool accommodation, as a comparison of Fig. 4 with the older designs will reveal. These recent developments in the direction of large area shallow work have probably rendered this range of presses the most popular of all the types at the present time.

When fitted with pneumatic die cushions and other devices, to which reference will be made later, they are transformed in effect into double-action presses, but it should be noted that they *raise* articles, as opposed to drawing them, as in the case of a double-action drawing press.

Deep Drawing.

Double-action toggle presses possess a number of advantages for deep drawing operations on articles with a balanced shape, such as saucepans, kettles, and similar work. The toggle arms when straightened out transfer the blank holder pressure direct on to the frames of the press, thereby permitting the entire use of the power of the crankshaft for the drawing operation. For long stroke work this is an important feature, because it will be appreciated that when raising metal on air, hydraulic or spring pressure, the pressure is put on by the crank, at, say, middle stroke, and is a sudden and permanent extra load on the press mechanism and power unit. The torsional load on the crankshaft increases with the length of the stroke, so that it will be seen that a single action press if fitted with a pressure attachment would need to be a much more powerful unit to overcome the resistance of this device at the point of the stroke where the torque strength is least.

In double-action presses, it is possible to draw the large articles straight through the tools, whereas this cannot be done on a machine with any attachment fixed under the bed. The tools for a toggle press, expecially for deep drawing operations, are simpler and cheaper than raising tools. This arises from the fact that the guides are provided in the outer slide of the machine, whereas in raising tools the pressure plates are supported on pins which come up through the bed and each one has to be machined and guided on the bottom tool or pommel.

Single-Action Presses.

Single-action presses, with shorter strokes, say up to 12 in., can be run at much higher speeds than double-action machines which, as has been shown, are usually made with very long strokes—frequently up to 36 in. The pressure on the blank holder can be varied or eliminated as required with great ease in these single-action machines fitted with hydraulic or air cushions. This feature is of the utmost importance when producing irregularly shaped articles, such as frequently occur in motor-car body parts, and which need special and differential pressure treatment to get the best results. These machines are also more suitable for combined blanking and

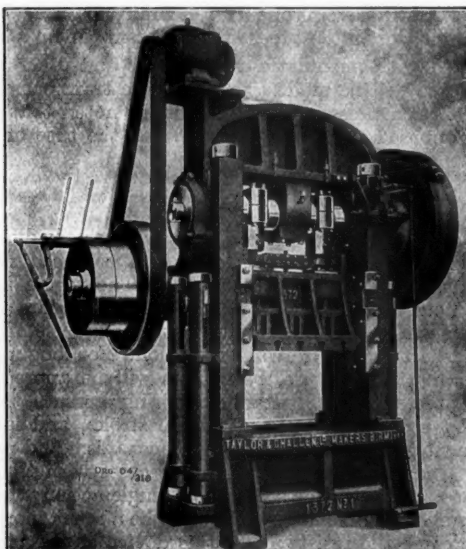

Fig. 4.—Large Single-action Press with Double-sided Frame.

drawing processes than double-action presses. It follows, therefore, from this brief summary, that the *work to be done* really determines which type of machine is the better for the purpose in view. Horizontal presses do not call for much special comment as they are really only ordinary single-action presses placed on their backs. This is usually done to facilitate the controlling of long tubular-shaped articles which would be difficult to keep in a vertical position.

Safety Valves.

The conversion of torque in a mechanical press to prevent breakdown is an interesting consideration and one which deserves brief mention here. The source of the power of a mechanical press is, primarily, the kinetic energy of the flywheel. It has been shown in the diagram of the coining press (Fig. 2) that the mechanical advantage of a toggle or crank increases enormously near the bottom of the stroke, and it is this fact which renders it impossible to insert an adequate safety valve in the form of a shearing pin in the flywheel, which would shear in case two blanks (or some other accidental happening which would have the same effect) were inadvertently put between the tools at the bottom of the stroke.

Presses are only broken by the stresses at the bottom of the stroke, and if the shearing pin has not been weak enough to give way before this position, the damage has been done. On the other hand, if it is weak enough to shear to ensure safety, it will never be strong enough to do the work.

Selecting the correct machine.

The following are the chief considerations which enter into the selection of the most suitable press for a given job : (1) Pressure required ; (2) the distance above the bottom of the stroke where this pressure is first applied ; (3) the amount of stroke necessary ; (4) the size and type of the die required ; (5) the amount of the pressure required to operate attachments which are used for drawing work ; (6) the size of the sheet or article to be operated on and also the method of feeding and the direction of feed may determine the type of the press ; (7) when the pressure occurs at or near the bottom of the stroke, the crankshaft is under a bending load similar to a beam and at this point will exert its full pressure within its listed capacity in doing operations which are performed in this bottom position of the slide, e.g., blanking, piercing, marking and coining ; (8) another point to take into account is the question of the position of the machine when at work. This consideration has special reference to the operation of combination tools in single-action presses. To get the best output it is often advisable to choose an inclinable press.

Press Tools.

A knowledge of the fundamental laws of mechanics is, of course, essential to the designer of the various types of machines which experience has shown to be suitable for a given type of operation. Knowledge of this kind, however, plays a secondary part in the design of the tools which are to be operated in them. It is probably

true to say that press tools are, as a class, the most intricate of all the auxiliary equipments of any kind of machine tool.

Skilled press-tool makers have developed their science or, better, art, empirically. In other words, they have accumulated their experience by observing various phenomena and recording the behaviour of the various materials when subjected to certain treatment. The method of trial and error may appear crude to the theorist, but here is a branch of service which is, undoubtedly, the product of practical experience.

The service rendered by the metallurgical research departments of the Universities, the National Physical Laboratory and other bodies, has been of enormous value to press users by reason of the vast improvements which have been made to the various kinds of sheet metals which are so widely used in the articles produced by these machines. For instance, it is now possible to draw a cup in mild steel to a depth equal to the diameter in one operation, and the author has some interesting samples demonstrating the effects of these improvements in the materials. It is no idle claim to say that press users have presented many problems to metal manufacturers, and many of them have been solved successfully.

These improvements have, of course, been accompanied by developments in the machines themselves, and the combination of these two factors is reflected in the enormously increased output and better quality of the articles which can now be made by these machines at lower prices.

The chief types of press tools in common use are : (1) Tools that operate by cutting or shearing the metal. In this class there are the following types : (*a*) Blanking ; (*b*) piercing ; (*c*) shaving ; (*d*) notching ; (*e*) shearing ; and (*f*) trimming or clipping. (2) Tools that shape the article by drawing the material and causing it to flow while under pressure control.

The operation of drawing a flat sheet of metal into a cupped shape of elaborate or simple design is possibly the most spectacular achievement of this branch of production. The new process of hot brass pressing also has its triumphs, of which mention will be made later, but in spite of startling results in this realm, some drawing processes still capture the imagination and leave the unitiated more or less incredulous.

It is true to describe the process as a " flowing " of the material. Under proper restraint from the top and bottom pressure rings, which are sometimes provided with a shallow projection and ironing groove respectively, the metal is forced into the die around the punch. It is interesting to note that the material always follows the shape of the punch in this process.

Drawing tools include: (1) Drawing dies (for a double-action press); (2) raising dies (for a single-action press); (3) bulging dies (in halves); (4) cutting and cupping dies; (5) redrawing and reducing dies (where metal is compressed inwards and not thinned as in extruding); (6) tools that bend or form the blanks which have previously been produced (these tools cover various bending, forming or edge-curling dies); and (7) tools that compress or squeeze the material causing it to be "upset" and pressed into different thicknesses (these tools comprise coining, extruding, extending, hot press pressing, and swaging tools). All the dies in the different groups are made in great variety, and in many instances they are combined one with another so that one set of tools may incorporate several classes of dies for performing as many individual operations upon the material at a single pass through the press. Such tools are variously known as: Follow-on tools; progressive dies; combination dies; compound dies, and the like. When

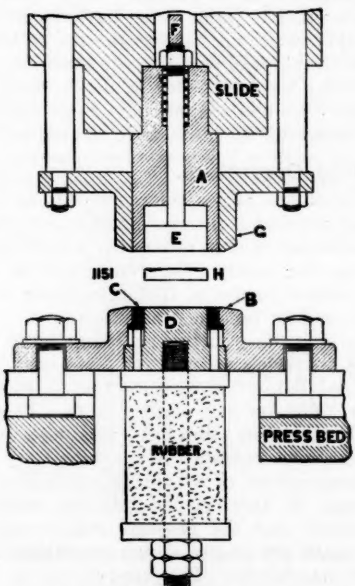

Fig. 5.—Cross-section of Combination Die for Single-action Press.

several sets of tools are operated in a single holder or sub-press, they are known as gang or multiple dies.

TABLE I.
Analysis of work done on Punches and Dies at the Park Gate Iron & Steel Co. Ltd., using a Taylor & Challen 600-ton Press.

Size in ins.	No. of times punch reground	No. of times die reground	Number blanked of different qualities					
			Dead Soft	Carbon 0.10/0.20	Carbon 0.20/0.25	Carbon 0.25/0.30	Carbon 0.35/0.40	Total blanked
12	5	3	15,532	16,719	64,758	3,851	—	100,860
16	8	3	1,151	73,181	4,197	34	51,513	130,076
20½	5	3	1,022	27,697	—	37,160	4,848	70,727
26	3	—	7,645	20,299	—	2,952	29	30,925
28½	6	4	16,922	30,536	—	—	—	47,511

A comparatively recent development in the general design of press tools is to build them into what is commonly called a sub-press. This device decreases the tool-setting time and ensures perfect alignment of the punch and die, and also reduces the maintenance charges to a minimum. These sub-presses may, of course, have their pillar or guide posts put in a convenient position to suit any special conditions, such as the size of the material to be worked or the available tool space in the machine in question.

Large dies of any sort and also intricate shaped dies are best made in sections. This method not only facilitates the making but also reduces the risks due to cracking in the hardening process.

Some Interesting Operations.

In this section of the paper reference will be made to certain devices of special or peculiar interest, in that they can often be used to perform operations which otherwise would be impossible or very troublesome and costly. Reference will be made especially to the use of various forms of hydraulic tools or dies in which rubber pads are used for bulging operations.

A 600-ton blanking press cutting out some large blanks of 40-ton tensile steel is in operation at the Park Gate Iron & Steel Co. Ltd., at Rotherham, and Table I gives some very interesting data about the performance of these and similar tools. This data has been freely supplied by this firm, who have produced over three million large blanks in three years from this machine.

Fig. 5 is a cross-section of a typical combination die used in a single-action press. In this type of tool the article is raised over the central pommel, and the pressure ring is supported on pegs resting on the plate above the spring or rubber buffer, or other type of pressure attachment. This kind of tool is used extensively in the manufacture of small cupped articles, e.g., telephone bells, cocoa-tin lids, and the like.

Hot Brass Pressing.

Hot pressing for many small brass articles has supplanted the

older process of casting. This new method might be called a controlled extrusion process in that the billets are enclosed on the sides and bottom in a collar (Fig. 6) or the top part of the die before the top tool or punch descends and totally encloses them. By the time the punch has travelled to the bottom of its stroke the red-hot (700 degrees to 750 degrees C.) billet will have been extruded or formed to the shape of the die in question. This method of totally enclosing the heated billet in suitable tools in a crank press is in opposition to the older method of hot stamping in a drop stamp or friction screw press where the billet was laid on the bottom half-die and was simply struck by the top die when it descended. One of the results of this cruder method of manufacture was seen in the formation of a considerable amount of flash or burr which is often entirely eliminated by the new process. This method is still in use for certain work not suited to the new process.

The following items show the important advantages which hot brass pressings possess over castings: (1) Components are non-porous; (2) metal improved by process (important in water fittings); (3) uniformity of parts facilitates interchangeability; (4) machining is reduced to a minimum; (5) finishing processes reduced to a minimum; (6) output much greater; (7) cost of production lower; and (8) scrap reduced to a minimum.

It will readily be recognised that many of these hot brass pressings are irregular in shape and call for dies to be made in halves so that

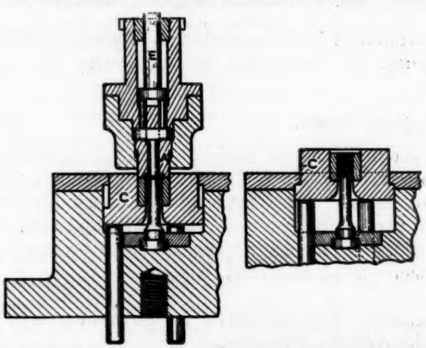

Fig. 6.—Showing typical Dies for making Hot Brass Pressings.

the articles can be removed after the forming operation. It was this fact which brought this attachment into being. Developments have taken place in the form of side and bottom motions which enable articles such as taps and valve bodies to be made with great facility and often in one operation from the billet.

Collapsible Tubes.

Fig. 7 probably shows a field of press work which is entirely new. It will be seen that the tools are quite simple in design, although a certain definite relationship between the punch and die sizes is essential to get the desired result. The results depend on the speed of the punch. It would appear that the initial velocity serves

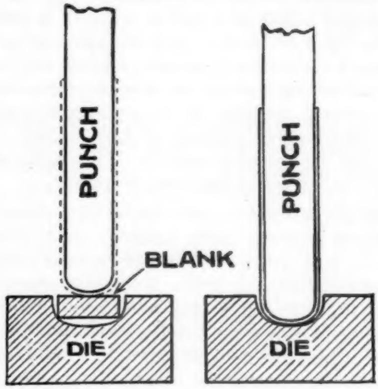

Fig. 7.—Tools for collapsible Tubes.

to lift up the remainder of the material. Tubes of different lengths can be obtained by increasing or decreasing the speed of the punch.

Rubber Bulging Tools.

To obviate the necessity for difficult spinning operations, awkward shapes can often be made by means of a punch made wholly or partly of hard rubber. This type of tool is usually operated in a double-action press, the pressure plate being used to hold the bottom split die. The dies, of course, have to be made in halves to enable the articles to be removed.

Special Pressure Attachments in common use on Single and Double Action Presses.

It is necessary briefly to distinguish between the various types. The old spring or rubber buffer pressure unit and the attachment known as the simplex pressure device must really be regarded broadly as tool equipment, whereas the pneumatic, hydro-pneumatic, and hydraulic die cushions are essentially part of the press equipment, as they are applicable to any job.

Although the last-mentioned attachments are usually fitted to single-action machines, it is necessary to stress the fact that by fitting them on double-action presses many jobs can be done in one operation which would not be possible without die cushions. A brief description of a simple form of air cushion is that it consists at rest of a cylinder or cushion in which is a piston, which in turn is connected by a piston rod to a pressure pad from which loose pressure pins extend up through holes in the bed of the press the underside of the pressure plate or blank holder.

When the compressed air which is confined in the cylinder, pipe-line and tank or reservoir is turned on the draw ring it is driven upwards and comes to rest under the blank to be operated upon. The tank and pipe-line are of such dimensions that the movement of the piston in the cushion does not vary the pressure to any appreciable extent. The air pressure in the whole system is easily controlled by one small valve (within narrow limits) and checked by a gauge.

In larger equipments numbers of cushions, tanks and controls are used, and the interconnecting pipe-lines so arranged that more or less or no pressure may be had automatically at any point in the stroke. In addition, it is possible to arrange to get varying pressures at different points on the press bed, a feature which is most desirable on uneven draws or awkward shapes.

By these means it is obvious that all possible contingencies are covered and any desired pressure of predetermined magnitude may be obtained automatically at any period of the press cycle. The controls are operated from and by the crankshaft, so that they are always in step with the press and each other. A full range of this type of equipment is made by the Worson Company, of Birmingham. The advantages claimed for this device may be summarised as follows : (1) Pressure constant or variable as desired ; (2) differential pressure if required ; and (3) tools can be reset at known pressures with great facility.

Hydraulic Die Cushion.

Briefly the action of the Carter hydraulic cushion is as follows : When the press is set in motion the top tool comes into contact with the pressure or draw ring and pushes it downwards during the formation of the article. During this forming process the fluid in the primary cylinder is ejected into the control cylinder by way of the sleeve pressure regulating valve, the setting of which governs both the quantity and nature of the pressure exerted on the blank.

This fluid in turn depresses the spring supported control plunger to about half of the depth of the article being pressed. This control plunger, on its upward movement, returns the fluid back to the primary cylinder but without its passing through the sleeve pressure

regulating valve, and in this way all the moving parts of both the cushion and tools are returned to their normal positions.

In larger cushions, the primary cylinders may be either single or gauged units, and when gauged can be supplied so that each unit can be used independently, and when all are in action, different pressures can be available in each unit. This feature is of the utmost importance in such work as the making of intricate panels or large pressings of irregular shape.

Formulæ for Calculating Pressures Required for various types of Presswork.

When designing tools for various operations in presses, the question usually arises as to whether the machine is capable of exerting the necessary pressure involved in doing the work. By using the following formulæ it will be possible easily to determine this pressure for different classes of work, and if the rules are carefully observed, the possibility of undue strain and fatigue in the machines will be eliminated.

If the capacity in tons of a single-action power press is not known, it can be calculated easily by taking twice the area of the main crankshaft at the bearings and multiplying the result by three. Thus, if the diameter of the shaft be 4in., the actual capacity of the press will be $12 + 12 = 24$ (sq. in.) $\times 3 = 72$ tons at the bottom of the stroke.

This formula only applies to crankshafts with two bearings. For end-wheel presses with overhanging crankpins multiply twice the main bearing area by 1.5.

Pressure Required for Blanking Various Materials.

Take the length of cut in inches, multiply by the thickness of the material in inches and by the shear factor in tons per sq. in. The following are the shearing factors for the different materials in common use for press operations : (1) Soft mild steel, 20 tons per sq. in. ; (2) soft copper, soft brass, or aluminium, 12 tons per sq. in. ; and (3) for harder qualities of steel take a figure equal to 75 per cent. of the tensile strength of the material.

It should be noted that these figures represent the *theoretic shearing pressure* and are correct when all the equipment is in perfect order. To counteract such possibilities as the defective grinding of tools, variations in the thickness or hardness of the metal, and incorrect tool setting, a further margin of safety, at the discretion of the user, is advisable to prevent fatigue in the machine, which, in time, may result in accidents. This more conservative calculation may be called the *practical shearing pressure*.

EXAMPLE : To find the pressure required to cut out a rectangular blank, say 6 in. $\times$ 4 in. $\times$ $\frac{1}{4}$ in. thick, length of cut $= 6$ in. $+$

4 in + 6 in. + 4 in. = 20 in. by ¼ in. = 5 sq. in. of metal cut. For soft mild steel this will mean a pressure of 5 × 20 tons = 100 tons, and for the non-ferrous metals referred to above, the pressure would be 5 × 12 tons = 60 tons.

The above pressures are correct for flat tools, but by putting "shear" on the punch or die, it is possible to reduce the load by approximately 20 per cent. It should be noted that "shear" is put on the die, and the punch left flat if the *blank* which is being cut is required to be *flat*. If, on the other hand, it is desired to keep the *sheets flat*, the "shear" must be put on the punch. No shear should be put on tools for cutting thin material—up to say $\frac{1}{16}$ in. in thickness.

The following is an additional list of the shearing factors for obtaining blanking or shearing pressures for various materials often used in single-action press operations.

Constants for obtaining blanking or shearing pressures for various materials (constants to be 20 per cent. less for punches having shear).

Aluminium castings	6.0
Aluminium sheets	10.0
Brass castings	18.0
Brass sheets (half hard)	13.0
Bristol-board (using dinking die)	1.5
Bristol-board (using flat-end punch)	2.5
Copper castings	15.0
Copper (rolled)	12.0
Fibre (hard)	11.0
German silver (half hard sheets)	16.0
Iron (cast)	20.0
Iron (wrought)	20.0
Lead	1.5
Leather (chrome)	3.5
Leather (oak)	3.5
Paper (using dinking die)	1.5
Paper (using flat-end punch)	3.2
Rawhide	6.5
Steel boiler plate and angle iron	20.0
Steel (cold drawn rod)	29.0
Steel (drill rod—not tempered)	40.0
Mild steel (0.45 carbon)	30.0
Steel (mild C.R. sheets)	25.0
Steel (soft mild)	20.0
Steel (nickel three to five percent)	40.0
Steel (spring 1.00)	42.0
Steel (spring 1.20 carbon—not tempered)	45.0
Steel (sheet tin-coated)	25.0

Steel (tool red-hot)	10 to 15
Strawboard (using dinking die)	1.0
Strawboard (using flat-end punch)	1.95
Zinc (rolled)	9.0

Pressure Required for Bending Operations.

Take the length of bend in inches, multiply by thickness of material in inches and by the bending factor in tons per sq. in. In this type of operation it is assumed that the material is merely bent and *not pinched or coined in any way.*

The bending factors for the various materials are: Mild steel, 10 tons per sq. in. approximately; harder steels, 20 tons; soft brass, aluminium, and soft copper, six tons; and for harder qualities, eight tons per sq. in. approximately.

Thus, in Fig. A, the length of the bends equals 8 in. + 8 in. = 16 in. by $\frac{1}{8}$ in. = 2 sq. in. of metal bent = 20 tons pressure required to do the work in mild steel.

Pressure Required for Drawing Operations.

(1) *In double-action presses such as those described earlier in the paper.* In such operations, the total pressure required is approximately equal to the amount for cutting out the blank from which the shape is formed. It should be noted particularly that the correct clearance between the punch and die is always provided.

In the case of double-action presses the total pressure should be divided between the pressure plate and punch in the proportion of 25 to 30 per cent. to the former, and 70 to 75 per cent. to the latter.

(2) *Where cups are formed in combination tools in single-action presses,* the total capacity of the machine must be equal to: (*a*) pressure required to cut out blank; (*b*) pressure required to form into cup and emboss; and (*c*) pressure required to compress spring or rubber buffer attachment, or air cushions, as the case may be.

The formula for calculating the size of blank for cups without top flange is $D = \sqrt{d^2 + 4dh}$. This is only correct when no changes take place in the area and thickness of the metal while the blank is being transformed into a shell.

Pressure Required for Embossing Letters, Figures, or Designs (Trade Marks, etc.).

This type of operation requires the same pressure which would be necessary for cutting out a blank of the same size. The operation must really be considered as a drawing operation, and it is assumed that the material is *not coined or thinned in any way.* When thinning or coining takes place, due either to faulty tool setting or thick

material, the pressure curve goes up enormously, even to as much as 100 tons per sq. in. over the area of metal pinched or coined.

Pressure Required for Coining Operations, such as thinning the material in squeezing processes cold, and pressing coins, etc.

For this class of work a pressure of approximately 100 tons per sq. in. for mild steel, and 60 to 100 tons per sq. in. for non-ferrous metals is required.

Pressure Required for Hot Brass Pressing Operations.

In forging yellow metal (60 per cent. copper plus 40 per cent. spelter) at a temperature of 700 degrees C. to 750 degrees C., according to the size of the billet, a pressure of 20 tons per sq. in. is required over the area of the article plus the area of flash which is formed during the pressing operation. It is essential in these hot pressing operations to do the work at the correct temperature.

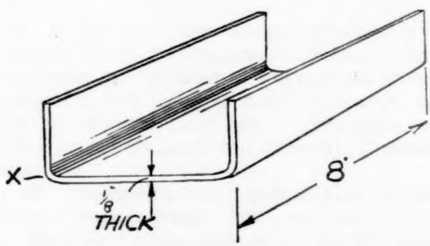

Fig. A.—The radius at × must not be less than twice the thickness of the metal.

Approximate Die Clearance between Punch and Die on diameter.

(*a*) Clearance for brass and soft steel: Take thickness of stock and divide by 10.

(*b*) Clearance for hard rolled steel equals thickness of stock divided by eight.

Table of Penetration.

The following table shows to what extent the punches have to penetrate into mild steel to effect complete severance of the material:

Thickness in inches ...	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$
Percentage of thickness ...	0.25	0.37	0.50	0.62	0.75
Equivalent in inches ...	0.0025	0.00185	0.00125	0.0008	0.0005

From this table it will be seen that the percentage of penetration of the punch into the thinner materials, before the metal is severed, is greater than for the thicker gauges.

Centre of Gravity of Irregular Blanks.

In the case of irregular shaped blanks, it is essential to ensure that the load on the press is evenly distributed, to find the centre of gravity of the cut. This can be done readily by bending a piece of fine wire to the shape of the cutting edges and balancing this formation of wire on a straight edge over two centre lines drawn at right angles to each other.

Discussion.

Mr. Craddock : I should like to take this opportunity of thanking Mr. Wilson for his most interesting lecture. There are one or two questions I would like to ask. In the first place, can Mr. Wilson inform us if there are any recognised limits for concentricity of an armature disk, say two inches diameter ? Some firms who make these parts, after assembling, grind to obtain balance, but with careful tool design I think grinding can be eliminated. Has he come across any press tools which have stellite on their surface ? I understand this is now being done and long life is claimed. Referring to presses, there was a press which he did not say anything about. That was the crank type of Bakelite press. Has any advance been made on that type ? It is a press which has been made in this country and also in Germany. Referring to the hot pressing of alloyed metal, are the tools cooled in any way—by water or air ?

Mr. Wilson : In the first place before answering Mr. Craddock's questions, I should like to pay tribute to the rapid development in the use of press tools in a number of ways North of the Tweed. I do not think there is very much in connection with certain special problems which you have to learn here. Your press work is not so diversified as it is in the Midlands but in certain directions it is very efficiently organised.

I will take Mr. Craddock's last question first—re the cooling of tools used for hot brass pressing. They are never cooled either by water or air. They are, in fact, kept at a " black " heat somewhere about 400°C. The steels used in the manufacture of the punches and dies for this particular branch of press work have been greatly improved in recent years, as the result of special research work by the makers.

The crank type of press for Bakelite moulding has been developed in this country. We ourselves make a machine which has all the characteristics of a hydraulic press. It is fitted with a powerful friction clutch which enables the operator to stop the press at any point of the stroke. The clutch is automatically thrown out at the bottom so that the full pressure remains on the material for the period required to " cure " it.

To mould bakelite powder a pressure of approximately two tons per square inch is required, and it is necessary to heat the material to a temperature of 175°C. At first it liquified at this temperature, but under continued pressure it soon solidifies at the same heat. The " curing " process takes from two to five minutes according to the nature of the material. There is a reduction from three volumes

to one in the finished article compared with the powder from which it is made.

I hope I am not saying anything to the despair of people who may be developing mechanical presses for this work, but I do not think they will ever compete successfully with hydraulic presses because they are much more costly. Our own machine is fitted with bottom spring pressure, which enables the die to follow the shrinkage of the material. I would say at once that it is possible to mould anything on a mechanical press which can be moulded on a hydraulic press. In the case of unit installations, there is probably very little difference in the capital outlay. Mechanical presses have several distinct advantages in that they are cleaner to operate, cheaper to maintain, and can be moved from place to place more readily. It is simply the question of the initial cost that is against them. I have had no experience of press tools which have stellite on their surfaces, but I have heard that it does lengthen the life of the dies. Mr. Craddock's first question touched on the limits to which a small two inch dia. armature disk could be manufactured on presses. With accurate tools carefully maintained, I think that discs could be made on which it would not be necessary to do any grinding or filing of the notches. I know that in the larger sizes of the discs such as are made by the B.T.H. and Metropolitan Vickers companies, practically no grinding or filing is done.

Mr. J. Kerr : The speaker gave us one example of pressing a tooth paste tube. I would like to know if it was necessary to closely control the metal which that tube was made out of and the speed of pressing. He indicated that by using different velocities he could obtain different lengths of tube. Can such a method be used in any other material than that which is used for the paste tubes ?

Mr. Wilson : It is necessary to watch the analysis of the materials that are used. Operations of this kind are limited to soft materials. Aluminium can be extruded in this way, but not as effectively as the softer tin and lead alloys. A punch speed of about 24 ft. per minute is normally used for extruding a 90 per cent. tin and 10 per cent. lead alloy. If the punch speed is being reduced or increased, it is possible to obtain different lengths of tubes.

Mr. L. Clayton : I should like to ask Mr. Wilson if he can inform us as to the degree of accuracy obtainable in the process of cold coining drop forgings.

Mr. Wilson : It is possible to get a great degree of accuracy in cold coining operations. There would not be a variation of more than one or two thousandths of an inch between a large number of articles made in one set of dies, such as some of the samples on view here to-night. In the case of such things as wing nuts and plier parts, to get the best results it is necessary to make them

from a blank as near as possible to the size and shape of the first operation. If you start with a blank of the correct thickness and shape, you can be sure of uniformity after the coining process. A pressure of 100 tons per square inch is required to " upset " or " coin " mild steel. For sizing operations such as on the bosses at the ends of small levers, like the samples on view, absolute accuracy can be attained and the dies are capable of sizing many thousands of articles. These sizing operations can be done at a fraction of the cost of milling. Drop forgings made from accurately cut blanks can be effectively sized at " black " heat by this method.

Mr. J. McFarlane : In the making of hot pressings, with the tools consequently at high temperatures, may we take it that the material for such tools will be of the stainless variety to overcome the large amount of oxidation which would otherwise take place? Regarding bakelite presses, it might be interesting to mention that a local firm does a small amount of work by using the pressure from the town water mains combined with some system of leverage whereby they get a greater pressure per square inch. I do not think their output is very great and their press was " home made " in their own tool room. I was interested in those spinning cop spindles—" fliers " I think they are called—drawn in about 19 operations. I would like to know if they are still being made for that work, as I am given to understand that one of the greatest difficulties met with in the experimental stage was the balancing of the press tool product suitably for their high rotational speed—about 30,000 r.p.m. In the latter stages of the experiment the parts were produced on special mandrels, made of Invar metal, by methods of electro deposition of copper, the mandrels rotating in the bath during the process. By this means a better balanced product was obtained, I wonder if the previous difficulties due to slight eccentricities in the press tools have been overcome?

Mr. Wilson : In reply to Mr. McFarlane's question as to whether the " fliers " were now being made by the method of " pressing " the answer is in the negative.

Mr. Hardaker : I should like to compliment the lecturer upon the sharpness and definition of his slides, and more especially, his films. Would he be kind enough to tell me the type of lubricant he would recommend during the pressing of various materials, such as, for instance, " copper "? Had he any experience in the pressing of such materials as " leather," because we, as production engineers, are interested in a variety of other materials than just iron and steel? Also, what was his opinion as regards the question of the driving of " presses " by means of various kinds of " belting " as compared with " direct " driving?

Mr. Wilson : I can only say there is a certain flexibility in a belt drive, which suits the conditions of a press operation. We now fit

many more tex-rope or belt drives on presses than direct geared drives. For pressing leather wood-pulp and cardboard, it is absolutely necessary to heat the dies to get the best results. In addition it is usually advisable to damp the material carefully. Eyeglass cases, jewellers' boxes, and shaped cartons are made in this way quite successfully. Other materials such as rubber, porcelain, fire-clay, can be pressed into shape in suitable machines and moulds. The question of the best lubricant to use during the process of pressing is difficult to answer shortly, because opinions vary. This is an important point, and I should be happy to get some information if it would be of special interest to members.

MR. G. BUCHANAN : In our firm the material dealt with is steel and is of much heavier gauge than any of the articles seen here to-night. Curious things can happen when making heavy pressings up to $\frac{3}{8}$ in. thick. I wonder if Mr. Wilson has any experience of this class of work made in hydraulic presses. In the making of domes or pots which were pressed hot, great difficulty was experienced in getting sound forgings until one day a leaky ram allowed water to enter the bottom die, and since then everything has been all right. The water cooled the bottom of the pot and in this way prevented cracking.

MR. WILSON : In reply to this question, there is a difference of opinion as to the necessity for holding the blank under pressure during the cupping process when the material is, say, $\frac{1}{4}$ in. thick, but in my opinion better pressings are obtained when pressure is used. I have very little experience of working material $\frac{3}{8}$ in. in thickness.

MR. W. PATE : Mr. Wilson referred to half a thousandth of an inch as a dimensional tolerance, and when such a figure is quoted I usually become sceptical. I wonder if any of the articles exhibited are produced regularly in big quantities within a fraction of a thousandth in any dimension ? As regards coining and using a petrol engine connecting rod as an example coined either cold or semi-hot, what tolerance of thickness would be reasonable to expect in the region of $\frac{1}{16}$ in. to $\frac{1}{8}$ in. in the web of the rod ?

MR. WILSON : I should really like to see a sample of the article to which you refer, before I could estimate the degree of accuracy you could get. A great deal depends on the uniformity of shape in the forgings before they were coined. I do not know of an article as large as a connecting rod eight to ten inches in length being coined, but I believe this is being done in the States. As previously mentioned, the bosses of levers can be coined to size quite accurately, and it would be true to say that this process is 50 times quicker than the old method of "milling."

MR. W. P. KIRKWOOD : In connection with the considerable saving which can be made in dies by the use of cast iron and putting

hard steel inserted pieces at the point of maximum wear, I think it would be interesting if Mr. Wilson could give an approximate figure for the cost of such dies for the wings for an eight h.p. Morris shown. Many of us would like to use special dies but our quantities do not warrant the expense. Dealing with thick hot pressing of say $\frac{3}{8}$ in. to $\frac{7}{16}$ in. material, what degree of concentricity might we expect between the outside and inside where this concentricity is of importance ?

Mr. Wilson : The cost of a typical set of dies for mud wings like the samples here would be about £500. The press for producing them would cost about £4,000. These articles are sometimes produced with much less expensive equipment. In this case the machines are small single action presses, in which " pancake " tools are used for the preliminary forming operations. The subsequent finishing is done by hand. It is interesting to note that the productions of this combined machine and hand work method are quite as cheap as those produced in the expensive machines with full tool equipment. Regarding the question of concentricity in forming a cup or brake drum, it is interesting to note that if the tools have been set properly the thickness of the walls of the drawn cups will be the same as the thickness of the blank from which they were made except for a very slight thickening round the top edge of the cup, and it therefore follows that so far as concentricity is concerned the articles should be absolutely correct.

Mr. Swindell : With reference to cold pressings. Do you press them wet or dry ? Is it your experience that it is better to use a lubricant of some sort ? With reference to blanking dies, used at a speed of 400 strokes per minute : can the speaker tell us the type of steel used in these dies ? As regards burnishing dies : has Mr. Wilson experience of these ? If so, what type of steel does he use ?

Mr. Wilson : It is usually better to use a lubricant of some kind when drawing materials through dies, though it is possible that aluminium is better worked dry. I know of one firm where they have suds pouring over the whole of the tools during the time pressing is being done. The steel used in the high speed blanking press for cutting out the chain links was Ultra Capital High Speed Plus 1, made by Keyser Ellison & Co. Ltd. Poldi steel is capable of taking a very high finish and I know is largely used in the manufacture of motor lamp reflectors, for which it is essential to ensure as good a finish as possible.

THE FUNCTIONS OF THE PRODUCTION ENGINEER.

Paper presented to the Institution, Edinburgh, Luton, and Leicester Sections, by W. G. Groocock, Member of Council.

Introduction.

WHEN we first approach this subject, "The Functions of a Production Engineer," we find an extraordinary divergence of opinion that is rather astonishing, and the more one thinks around the subject the more indeterminate the main elements of our problem appear. Our first thoughts are that these functions—whatever they may be—must, of necessity, have some reference to the kind of commodity that has to be produced. It appears, too, that the functions may also be influenced to a considerable extent by the size and type of organisation to which the engineer is attached. But is this so ? I think not ! My belief is that the functions of the production engineer are the same in all cases, but type of product and size and type or organisation do affect the methods used when carrying out these functions.

If this reasoning is correct it would appear that the best way to approach our subject is to try and find something that is fundamental and from that deduce certain conditions that follow of necessity. From these conditions and the circumstances that surround them we may possibly obtain a brief summary of the functions that are definitely required in production engineering.

Whenever I think of the title of "Production Engineer" I am reminded that we have never yet—so far as I know—been able to define what it is. In the opinion of some people he is nothing more than a progress clerk with no executive control, while in other circles he is the dominating influence on the manufacturing side. Personally, my opinion inclines toward the latter point of view.

Production Management Technique.

This session our Council have arranged as a subject for all sections one called "Production Management Technique," and the attempt behind this series of lectures is to see if there are any possible first principles, or fundamentals, whichever you like to call them, that can be used as a starting point in turning the art of the production engineer into a science. If the problem is properly stated and dis-

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cussed we shall, no doubt, find a number of common points, but we have to recollect that 95 per cent. at least of the engineering establishments of this country number less than 250 employees. Consequently, it is extremely difficult to see any scientific connection between the technique of the production engineer of one of these smaller shops and that of the production engineer attached to a works of 10,000 employees or more. Yet, undoubtedly, there is common ground. Daily these small shops are doing precisely the same work as the larger establishments but doing it in a different way.

I think, therefore, that in approaching this question of the functions of production engineering we must always keep in mind the fact that whilst the functions are the same in the case of both large and small establishments, the number of people engaged in carrying out these functions is so different that we are apt to lose sight of the fact that there is any degree of similarity. In the present paper, however, we are not concerned with the technique—or methods—used by the production engineer as these may, obviously, vary with the size and type of organisation. What we are concerned with are the functions that must be performed if the production engineer is to live up to our conception of his job.

We must recollect that although we speak of the production engineer it does not, of necessity, follow that the production engineer is concerned in the manufacture of an engineering commodity. He may, and will I think in the future, control production in practically every one of the large scale organisations that manufacture foodstuffs, biscuits, glass, and all the many other commodities that go to make life worth while, but for the purpose of this particular paper we will consider that the production engineer we are talking about is engaged in the manufacture of some engineering product, such as machinery, motor cars, etc.

What is a Production Engineer ?

It will be agreed, I think, that before we attempt to get a line-up on the functions of the production engineer, we ought to reach an agreement, if possible, on the question of : " What is a production engineer ? " " What is his work ? " and " What are his problems ? " We know that there is no word more abused than that of " engineers," and we have our choice between the engineer in charge of a small stationary pumping plant—who is nothing but a stoker, and the man in charge of the erection of a large bridge. This being so, I do not propose to attempt to define what an engineer is. It will be more useful, I think, to attempt to deal with what an engineer does—and that is engineering.

The best definition that I know is, " engineering develops and standardises, translating the scientists' work into practical appli-

ances for human good." If we accept this, then the obvious definition for, or of a production engineer is that he is a trained engineer who is engaged in producing by mechanical means, and otherwise, any commodity which will maintain or improve the standard of comfort of the community. These commodities he must make from any and all the materials that nature and the scientists have placed at his disposal. His chief function is that of devising ways and means to increase the productivity of the particular plant to which he is attached.

There is nothing new about the production engineer except the title as he has existed under various definitions since the beginning of engineering. He owes the title, undoubtedly, to the fact that as engineering became more complicated it became necessary to specialise, and as a consequence we now have a type of engineer whose training and mentality fit him for the position of producing the goods as distinct from that of designing them. While the general training may be the same in both branches in the early stages, when specialisation takes place, then one finds, of necessity, that the outlook—of these two sides of engineering control—begins to diverge. One—the designing engineer—thinks mainly in terms of machine performance, while, the other one—the production engineer—thinks in terms of time, price, and quality, having regard also to the equipment he has available for use. We see, therefore, that under modern specialised conditions of engineering there are different viewpoints right at the beginning, and it is the function of the production engineer to see that these viewpoints are not divergent ones. This point I will refer to later.

Having now arrived at a basis on which to outline the work of the production engineer, we can, I think, go through the work of such a man and get some idea of the main functions covered in his ordinary day's work. His main function—as I have already said—is concerned with "devising ways and means to increase the productivity of the plant to which he is attached."

I want you to keep in mind the fact that we have no common line of titles in our industry, and that the production engineer, whose work I propose to talk about and summarise, may be purely a mythical character in some establishment. In this connection I want you to realise that titles mean nothing at all. What we are concerned about is not the title of the individual, but the work that that individual has to perform. The production engineers then that I have in mind are those whose responsibility it is to produce the commodities required.

A Summary of the Functions.

The time at my disposal will not allow me to explore fully the whole of the problems connected with the work of a production

engineer. This being so, I propose, first, to state a specific case so that you will get a general view of the field that is being covered, and then to follow this with a summary of the functions necessary to satisfy such a particular case. Following this, I will take a few of the main functions and examine them more closely, giving my own views on certain aspects that arise from them. I would, however, once more repeat that it is not my intention to deal with the technique of the matter. All we are concerned about to-night is just what functions the production engineer has to perform.

Now for the purpose of this paper I am going to assume a hypothetical case where the production engineer has had handed over to him the design of an article, or a series of articles, with all design details complete ready for manufacture. The cost at which he has to manufacture is also stated and the rate of manufacture has been roughly outlined to him, with commencing dates clearly laid down. His problem in such a case then is to analyse the design, plan a series of operations that will give him the necessary quality of work, co-relate these operations to time, so that the question of delivery is taken care of, and further, he has also to see that the cost factor at this stage looks in line with the final cost requirements. In his plans the production engineer must ensure that material of the right kind is ordered, and that the delivery of same will line up with his requirements in the works, having regard to the works' capacity to absorb such material. If the material comes in too early there will be a definite and unnecessary tie-up of capital which is undesirable, whilst on the other hand, if the material is late there will be a still more undesirable delay in the works—a delay which can never be made up.

When the production plans are being developed, as regards operations and materials, the production engineer must also closely examine the load on his shops, so as to see that no "bottle-neck" will develop. We have always to remember in cases like this, that whatever system we are using, the overall rate of flow of the product is governed by the slowest department. It is highly desirable, therefore, that a close analysis of shop load should be made so as to expose the possible "bottle-necks" before they actually occur. If this is done, then steps can be taken to meet such conditions either by the installation of new plant—if it is a question of a machine or two—or by arranging to have some of the work in question done at other plants. Possibly, when fully analysed, he will find out that under the best circumstances that can be imagined the load cannot be taken with his present plant, and one or other of the steps mentioned above must be taken. If, of course, his plant is sufficient by working overtime or two or three shifts, then it is extremely convenient to know this at an early stage because arrangements can be made to get in a sufficiency of labour to meet the case. We have

to remember that it is not always possible to obtain the necessary labour when we require it, and in our special case it may possibly mean taking labour from some other work that is going through the shops. This means fully exploring the whole of the work that is being done to see whether it is possible to ease up on some other work for the benefit of the new design. Balance of product is very desirable at all times, but at no time is it more desirable to keep this in mind than when pressure of work, coupled with new products to make, comes along at the same time.

The material having been ordered and the time schedule made out both with regard to the delivery of the material and the expectations at various stages in the progress of the work, this information must be conveyed to the stores and to the shops so that each separate part of the organisation shall have the earliest possible information as to what is expected of them. This also applies, of course, to the dispatch section so that they can function in line and in time with the rest of the organisation. This summary very briefly outlines the main functions of the production engineer.

Now let us look more closely at several of these functions, with a view to examining those off-shoots which require personal attention from the production engineer.

Suitability of Design.

In our summary of functions the first one mentioned was to analyse the design prior to planning the necessary series of operations. Now amongst the very many factors that affect the production engineer's problem there is one which, in my mind, dominates the whole, and it is this factor that may be of such importance that it will really control the success, or failure, that may follow his very best efforts. I refer now to suitability of design under the conditions of manufacture that are, of necessity, forced on those in control of the manufacture. This suitability, or otherwise, can only be considered when all the factors are known, because such factors as quantity, rate of output, and type of plant where manufacture is to take place all have a bearing on this question of suitability of design. This being so, when he first goes over the drawings with a view to a preliminary lay-out of operations, etc., the production engineer must always have at the back of his mind a series of questions regarding each component and also for the mechanism as a whole. The more he knows about the type of manufacture involved the more surely will he see at each stage of his planning any points in design which will make for trouble in the shops. When difficult design is met he must so arrange his operations that such pieces can be made with a minimum of loss.

Now those of us who have had some experience along these lines know that it is really difficult to get the designers to alter a design

once it is fully established in its final drawing form. Consequently, in my view, it is very necessary, where possible, that the production engineer examines drawings before they become complete designs.

The question as to whether the production engineer should, or should not, have any connection with the design itself has been discussed on many occasions and is always left more or less indefinite. There is one school of thought that would argue that the production engineer is not interested in the design and should not concern himself in any way in this respect. There is another school of thought which believes that the best results are obtained when the production engineer can form some contact with the designer before the design of the articles, mechanisms, or whatever they are, become permanent. My own view in this respect is that it is highly desirable that the production engineer should have an opportunity of examining the designs when they are on the drawing board, that is, before they become an actually completed design.

It is well known that designers, as a rule, are not completely *au fait* with shop processes. In many cases they do not know, and sometimes they do not care how the piece is to be produced. They visualise the mechanism and design it to give them the movements that are desired. This is done quite often without full knowledge, or with very little knowledge, of how the piece will be made. I claim, therefore, that if the production engineer, who is responsible for making the article, is to be held responsible for the quality of the work, for the cost of making it, and for the time in which it is to be made, has some knowledge of the design before it becomes final, he can very often indicate to the designer ways by which, without departing seriously from shape, without detracting anything from its functioning, an article can be made more easily in the shop under his control—not only made more easily, but cheaper and more accurately.

If I am right in this view, then, quite obviously, the production engineer should be called into every design which will pass through his hands at a later stage. He should see them in the design stage, and there should be complete and positive co-operation between designer and production engineer with a view to getting out designs which, whilst being entirely suitable from the designer's point of view, will also be suitable for making in the particular plant where they must be made. This co-operative blending of design and works will always be a good thing. The designer will be able to get from the production engineer a sympathetic consideration for his designs, and the production engineer will be able to impart to the designer himself that sense we call " shop sense " which may have a material influence not only on that design but on subsequent designs that come from the same source.

From the production engineer's point of view it has great advantages. He knows the possibilities of the plant under his control. He knows, too, or should know, its limitations, and when a design is coming through, and he has an opportunity to examine it on the drawing board, he would at once see where he was going to have difficulty with his existing plant. He would see at that stage two alternatives, namely, an alteration in the design which would allow him to make the particular piece, or pieces economically, or new machinery to cater for the particular pieces in question. There would be the further alternative which would be getting such pieces made outside the organisation. If, as I have said, he has an opportunity to go into this before the design is fixed the production engineer is in a much better position. If he cannot suggest any changes in the design which would be helpful to him with his own plant he can at once take steps to examine the situation as to his other two alternatives, namely, the provision of fresh machinery or of putting the work outside to be made.

There are still many who, as I have said before, want to utterly divorce design from production. They would claim, and have claimed that if the designer knows too much about the producing side he gets " cramped " in his ideas, loses originality and becomes a mere follower of prevailing fashion. My own view is that a man whose sole interest is design will never know sufficient of the production side to get any serious " crippling " in his style through this knowledge, but I do claim that close co-operation between the designer and the production engineer is to the benefit of both. On the one hand, the production engineer can impart to the designer something of his own production mentality—that mentality which is determined to always make things better and cheaper. On the other hand, the designer himself will be able to impart some of his enthusiasm for his designs to the production engineer, thus ensuring that those little things in the design which do not always appear on the drawings will receive full attention.

Planning.

The second function mentioned in our summary was to plan a series of operations, etc. The primary object behind all planning for production is to assure ourselves, so far as that is possible, that we get as the result of our planning, first, a product the quality of which shall be up to the standard desired ; secondly, that the product is down to the price required so that it is competitive and can be sold ; thirdly—and probably most important of all—to see that the product itself shall be in the hands of the customer in the time desired. These three points will be referred to again later. Since the greater bulk of our engineering establishments are well

below 500 in the number of their employees there is a feeling that planning is not a possibility. I do not admit this.

No matter what size of organisation the production engineer is attached to, planning in some form or other is a necessity. The methods by which such planning is achieved will differ materially according to the size and type of organisation, but whether the plant be large or small, whether the work being performed is a case of single articles or repetition, the principle governing the planning is the same. The production engineer has to cover and cater for the same various details in each case, thus he must purchase the material, or see that it is purchased, first, to the specifications as laid down by the designing engineer, and secondly, make arrangements for the delivery of each of the various materials as to the date, rate of delivery, and sequence desired.

The designs must be gone over step by step, each component being dealt with, first, as to the sequence of operations, secondly, as to the jigs and tools required. He has, further, to arrange that piecework rates are fixed, or times, whichever the case may be, for each individual operation, and he must, of necessity, to safeguard himself, see that his cost department takes the rates so fixed and checks them and the cost of his material against the original estimated cost of the work he has to produce. Further than this, he must arrange that both the raw material and the finished articles be subjected to inspection at various stages to ensure that the quality of his material and also his finished work is up to the standard desired. That is the general proposition that comes under the heading of "Planning."

I want you to bear with me now for a few minutes while I go over several of these items in some detail.

Material.

We are now passing out of the stage where there is a difference of opinion as to whether the production engineer should, or should not, control the supply of material. It is not, I know, quite general that he should control this line, but it is absolutely logical that the man who is responsible for the delivery of the goods should also be held responsible for seeing that the material which he has to use is ordered in such a way that he may expect to get it in roughly at the rate at which he wants to use it, and that the delivery shall start at or about the time when he wishes to first commence operations on it.

My own view is that unless the production engineer has control of this essential service of his, namely, the purchase of his raw material, then there are huge possibilities that we shall have one of two things happening—either the material will come in too soon and there will be a heavy tie-up of capital in inventory, or, alternatively, there will

be delay in getting the material with consequent loss of time in making a start. Both of these are detrimental. Both entail a fairly heavy loss.

Since we shall hold the production engineer responsible for the delivery of the goods then, I think we must, to be wholly logical, hold him responsible also for getting in the materials from which to make these goods. Given that the material has been ordered, this means that all the drawings have been gone over from the point of view of quantity of material required, and during this stage of the planning a good deal of knowledgeable information has been acquired by those who have been going over the drawings. This is definitely useful experience when we come to sit down and plan individual operations for each piece of mechanism we have to manufacture.

Just how the work will be done depends, as I have already mentioned, on the size of the organisation. In the larger organisation the planning department is so large that there are specialist heads to each of the various sections. One specialist deals with the ordering of the material; another specialist and his helpers deal with the sequence of operations for individual components; a still further specialist deals with the question of the jigs and tools required; whilst other specialists deal with rate-fixing, and so on. In such an organisation there are huge possibilities that each and all of these specialists work solely for their own ends. They only see their own point of view, and unless extreme care is exercised by the production engineer there will be tragic losses owing to the isolation of these various special sections.

The one thing in a large organisation that the production engineer has to guard against is the question of water-tight compartments in such cases. Water-tight compartments do not make for efficiency. They definitely are tending all the time to inefficient methods. There is a bad, or unbalanced, use of the labour involved in each of the sections, and there is a tendency in all such cases to too much letter writing, too much shirking of responsibility. Water-tight compartments of this order then should be avoided as far as it is possible. On the other hand, in a small establishment the production engineer closely controls all these various operations. He is in on the ordering of the material; he is in or has a voice in the sequence of operations; he takes an active part in going over the loading of his various tools to see that he has capacity, which is part and parcel of operation planning; he is closely in touch with, or actively engaged on the question of rates to be paid, and he must, of necessity, have a very close knowledge and association with the cost department, which has to give him the necessary information. In the larger organisation he can only keep in touch by means of the head, or through the head of the various special

sections. In the smaller organisation he can, as I have said, be actively engaged sitting in conference with them at stated intervals. Whichever way is adopted, however large or however small the organisation may be, those functions that I have just mentioned are amongst the most vital functions of the production engineer.

Now I want to specially refer again to those three points I mentioned as being our objectives when planning. The first of these dealt with quality.

Quality.

In any established works of note a standard of quality is set up and must be maintained, and it is the function of the production engineer to see that, apart from suitability of design, the materials used, the operations that are necessary, and the jigs and tools which are provided are such that there is a reasonable certainty that the quality laid down can be maintained. In some establishments the inspection itself is outside the jurisdiction of the production engineer, but if the best results are to be achieved there must be close co-operation between the production engineer and the chief inspector, with a view to ensuring that the company's standard of quality shall be maintained. When there are lines of demarcation that are too rigid between the production staff and the inspection staff too often there is an undue amount of scrap which could have been avoided had there been proper co-operation at the beginning of the job. Too often it happens that all the inspector can do is to say that the work is not up to standard. At this stage, of course, it is sometimes too late to save quite considerable batches of work—too late because the primary steps ought to have ensured that it was, in the bulk, up to standard. This co-ordination of the productive side with the inspection side is clearly one of the functions of the production engineer.

Price.

Another of the points mentioned at the beginning of planning was that of price. In these competitive days we know that unless our price is right we do not get the order, and one of the functions of the production engineer is to ensure that the estimate of prices on which we received the order is either maintained in practice or improved upon. This means a very close control of the purchase price of material; the rates paid for doing the work; the cost of developments for tools, etc., and many other points. In this connection there must be very close working between the production engineer, his rate-fixers, and his cost department, and these will be referred to at a later stage.

The third essential to planning mentioned was that of time.

Time.

Most of you, gentlemen, here to-night know how important delivery times are. To-day, probably as never before, the question of delivery time often influences the order. In other words, we may fail to get an order if our delivery time is too long; whilst, on the other hand, if we fail to deliver in the time we have promised we have failed in our idea of service to our customer and this means a disgruntled customer. We see, therefore, that another of the main functions of a planning department is the fixing of a time schedule for the whole of the operations involved, and, what is more, close control of that time schedule so that the times so arranged are actually carried out.

Now all of the three main points regarding planning which I have mentioned are very vital points and each of them is definitely interlocked with each of the others. The main function, therefore, of the production engineer in this connection is to explore the problem from his own angle and to find out how each of these can be obtained and the best way of organising to get a correct balance in each respect.

Arising out of what has been said about the three main functions connected with planning, and particularly that section of the planning which refers to the price of the article, we have to deal with rate-fixing and costing, and these are of sufficient importance, I think, to devote some little time to.

Rate-fixing.

As soon as the planning department have made a decision on the question of manufacture; have decided on which type of machine they will do the work; have definitely gone over the question of jigs and tools that will be made; then we come to the question of fixing times, or rates for performing the various operations. This then introduces the rate-fixer, and if he is to do his work in an efficient way he must have some knowledge of the original estimates for the work. We have taken on the work at a certain price and this price will be based on so much material, so much for labour, so much for overheads and perhaps a small allowance for unforeseen difficulties, plus a profit when any is expected.

Now unless we are to lose money, the rate-fixer must be extremely careful in fixing his times, or prices, so that the sum total of all such prices shall not exceed the amount allowed for in the original estimate. He is not concerned with the material, but he certainly is concerned with the labour side of the problem, and it is up to the production engineer to see that the rate-fixer has the fullest information on the question of what is expected in the way of labour costs. When the rate-fixer knows this he can go thoroughly into the matter, and if he cannot make all his time balance he must then bring this at once to the notice of the production engineer.

The alternative to this is, of course, putting on the prices that can be met and finding out when the work is actually finished that a loss has been made. This is not the right way to do it. The production engineer should have early information that there is likely to be a definite loss. He can then investigate the situation and see whether anything in the nature of special tooling, etc., will turn this probable loss into a balance on the right side. Since this condition is a necessity it shows very clearly, I think, that the rate-fixing section must be under the control of the production engineer, if not directly, sufficiently close for the production engineer to have an influence on what is going on.

Costing.

Much of what has been said regarding rate-fixing is also true of costing. The rate-fixer normally is not concerned with anything beyond the direct labour cost of either an operation or a series of operations, but the cost department have, of necessity, to apply the overheads to the direct labour and from that and the material cost then derive the actual cost in the shop. They may, under special circumstances, have to add something for development, but, in any case, they have, or should have, all the information available to do this work, and a combination of the rate-fixing and cost departments will definitely be able to keep the production engineer informed as to how he stands on the cost side.

I have mentioned the question of overheads in this connection, and I would definitely like to say that this question of overheads should receive much more consideration from the average production engineer than it does at the present moment. Unless due regard is paid to this factor he may find that although he has a low labour charge his costs are still too high. There are many cases known where it has paid to spend time in evolving methods of saving on the expense side, that is, the side which affects our overhead charges, rather than to spend such time on the production side.

Statistics.

A glance through technical journals and also through the published Journals of our Institution will serve to show how much our attention is being directed towards the importance of statistics as an aid to production problems. A close analysis too will often show that statistics are still being regarded as the "end" instead of the "means" to whatever they are concerned with. Cases have been known where the statistical systems have been so perfect as to be a positive danger to the users who count on their system telling them what *has* happened, instead of having a system which is likely to tell them what *will* happen. It is only half the story to know what our costs are after they have actually been incurred. What we

want is advance information on what they are likely to be, so that from such information the necessary correctives can be applied to see that our costs are in line with our requirements.

If we have a correct perspective we shall know which of our statistical compilation is merely " wisdom after the event " which, as you all know, is one of our cheapest commodities. Yet, in the case of such wisdom as is sometimes found in statistical summaries, anyone can see that it is not cheap in a financial sense. Too often these summaries are costly to compile and generally are out-of-date before they are issued.

Statistics can, however, be of great use to the production engineer when used, as they should be used, as tools. The circumstances of their compilation should be thoroughly known to the production engineer, so that when comparing one set of figures with another the variables should be known and the interactions from such variables can then be evaluated. Too often, however, we find comparisons being attempted between various sets of figures, the basis of these sets being entirely different. Clearly then, in this question of costs, and statistics generally, we have another of those functions that must receive the earnest attention of the production engineer.

Control of Production.

When all the plans have been made and operations and prices arranged, further, the material is ready, we still have to see that orders are given to the shops in such a way that no indefiniteness can exist as to when such parts are required to complete our general scheme. Too often plans of the super order are made and then the whole scheme is nullified because there is no definite tie-up between the plans that have been made and the people who have to do the work. It should be remembered at this stage that a second-rate plan which is properly carried out is far superior to a first-rate plan where there is no follow-through to ensure that it is carried to completion. There have been too many cases in the past of this order. There has been too much dissociation of the planning and the actual carrying out of the work. This is due to what might be termed " over-departmentalism," where the department concerned can say it has done its work and does not care one iota so far as the next link in the chain is concerned.

Too much emphasis cannot be laid on this particular phase of production engineering. There must be continuity of effort right from the plan to the completion of the work. If such continuity does not exist, then there are bound to be failures, and these failures will result in an over-expenditure and, almost to a certainty, in a late delivery. One of the greatest drawbacks that exists to certain planning departments at the moment is this missing link between them and the actual producers. The orders may be given, but

unless there is a follow-up system there is a great probability that amongst those orders there will be something on which time will be lost and sometimes quite a considerable time before explanations are demanded. Time lost can never be regained.

Toolroom and Tool Design.

Another very important function of the production engineer is the design and manufacture of all the special tools, jigs, fixtures, and gauges required for making the product that he is concerned with. In this connection his first problem will probably be in trying to make up his mind as to which department shall be responsible for the design of such tools, jigs, etc. Quite obviously, the question of special tools, etc., that are required for any particular line of work must be settled early in the deliberations of the planning department, because planning means processing, and when we get to processing, or job lay-out, then we must definitely decide what special jigs and tools are required. Quite obviously too, before we can fix rates, which is another of the functions we have dealt with, these special tools, etc., must be definitely determined.

This part is quite clear, but the question of who shall actually be responsible for the finished design of such tools, while it is an extremely important one, is sometimes difficult to lay down in view of the complexity of any particular organisation. For instance, the planning department, as a department, might be fully capable in this respect. In fact, in several cases known to me the designs of such tools are always under the control of the head of the planning section. In some cases, however, the final result is not always what it should be.

Tools, jigs, and gauges must be made in such a way that they can be used under the conditions imposed. Sometimes, yea, often, this means a considerable amount of experimental work, and when the design is divorced from the actual manufacture of the tools and jigs, there is likely to be considerable delay over every little point that may arise. For instance, the toolroom may say that the tool or jig is to drawing, whilst the shop says they cannot apply the jig or tool to the work. On the other hand, when the jig or tool is applied the inspection department may report that the work is not according to the drawing of the particular product, and yet, according to the toolroom, the jig is right. It is on such points as this that there is something to be said for having the design of jigs and tools come under the same control as the making of the tools. In fact, in my own experience the best results have always appeared to follow when the design and manufacture of such equipment comes under the same departmental head.

This is another of the very many cases that will be found in practice so difficult to arrive at any definite conclusion. Nearly

always a compromise may be necessary and the solution may have to be found in judging between the capacities of various heads of departments. We have to remember in this case, as in many others, that the best man at coming forward with ideas is not necessarily the best man to bring such ideas to fruition. On the contrary, quite often he is the worst, because as soon as he strikes a difficulty he wants to wander off into another idea altogether. Usually, too, such individuals have no " time sense " and will waste considerable time on pursuing what is really a " will-o'the-wisp." Decision in such cases as to who is to control the design then must depend very largely on the personnel of the organisation.

In connection with tool work generally it is very necessary that the production engineer shall have his finger on the pulse of all tool costs. This is extremely important from two points of view, namely, (1) the question of keeping tool charges down to a minimum, and (2) having readily available tool costs so that they can be used in any subsequent case of estimating that has to be done on similar apparatus.

The Foreman.

One of the weak points sometimes in a planning system is that the foreman in the shop is not brought into consultation during the planning scheme. We have been told many times that when work has been properly planned the position of the foreman becomes relatively unimportant. I want to say here that I entirely disagree with this idea both as a statement and as a fact. While it may be true that under certain highly developed types of quantity manufacture the position of the foreman is not what it used to be, you will invariably find that the old foreman has not disappeared, neither have his functions. There are very few establishments in this country that can afford to ignore the valuable experience of their shop foreman. It is true that in some of the larger establishments the functions of the old foreman have been taken over by a superintendent and that the new foreman is what used to be known as the chargehand. If we regard this matter from the aspect of the work that has to be done, rather than from the title of the personnel who does the work, we shall find that the foreman, superintendent or departmental manager is just as important under pre-planning as he was before planning became a feature in production engineering.

The production engineer must definitely see that there are not watertight compartments in his organisation. He must see that the material and information which he starts flowing down his stream must have unobstructed progress until it reaches the reservoir, that is, the dispatching store, in the form of a finished article. It is not only at this point that he must pay particular attention to keeping the line clear, but I have emphasised this one largely be-

cause the assertion is so often made and repeated that if we have a planning department we need less skill and experience amongst our foremen. Some, indeed, have asserted that if you have a foreman with experience he should be put into the planning department and his place in the shop taken by a progress clerk.

This course may be suitable for factories working on one type of product with large quantities, but it certainly is not the best way to deal with the problem when quantities are smaller and types are numerous. I doubt also whether it is the correct way to deal with the problem when types are few and quantities are large. I doubt also, if you explored any of these larger organisations, whether you would actually find that such a condition existed. It gets talked about and sometimes has been put into operation, but usually falls down very badly for a variety of reasons. This one small section coming under the general heading of "foremen" is well worth considerable thought, but it is only one of many that the production engineer has to deal with.

Maintenance Force.

We can, I think, agree that the man who is responsible for production must have some sort of control over every factor that affects such production. If this is granted, then, as a corollary, the production engineer must control that part of the organisation which is responsible not only for purchasing new machinery and equipment but for keeping all plant in a satisfactory working condition at all times. Unless the production engineer does have this control he is not in a position to dominate the situation when the question of precedence of repair arises, and my view is that the maintenance force must come under the control of the production engineer so as to have a proper co-ordination in all those factors which so affect production. Particularly is this so in the factor of maintenance of equipment at a high level of efficiency.

There is another point about the maintenance force that I would like to raise at this stage, and that is, the changes in personnel that have become necessary of late years.

The general tendency to-day is to use electrical equipment coupled directly to machine tools in an ever-increasing quantity. The machine tool makers and the makers of electrical equipment are getting closer together every day in this respect, and we can look forward to the future of an ever more increasing electrical side to our machine tool equipment. This means that our maintenance department to-day must have in it a strong section of men with electrical knowledge, men who are not merely wiremen, but men who thoroughly understand the fundamentals of the electric motor and the various types of electrical equipment used to-day in the modern engineering works.

It is necessary to have thorough co-operation between the electrical side and the mechanical side of our maintenance so as to keep our equipment in proper running order. Whether they are to be two sections under two departmental heads, or whether both sections shall function under one head is a matter which can only be settled by a knowledge of the organisation and its personnel. It is, however, one of the functions of the production engineer to see that his equipment reaches a high standard of efficiency, and when he is considering his maintenance problems he must take note of this constantly increasing importance on the electrical side from the point of view of purchase, installation, and maintenance.

Stores Control.

It will be agreed by all that stores control is one of the functions of the production enginner. He must control not only the ordering and stocking of his raw material, but he must deal also with the semi-finished and finished material. In this question of stores control he will meet another of those very serious stumbling-blocks which are frequently met in connection with manufacture. This is particularly so if he happens to be making a number of types of apparatus the demand for which is not regular and the manufacturing time for which is short. Many of us know that when such conditions obtain the stores are apt to grow and keep on encroaching on the manufacturing space. Unless careful watch is kept they are apt to get out of control. To obtain a proper balance as between manufacturing and storage space, therefore, is a matter which requires extreme watchfulness.

The question of how much stock of either material, or finished parts to carry, is one that must also at all times be under constant scrutiny so as to see that the tie-up in capital that is involved is really justified by the conditions imposed.

The ideal manufacturing scheme would be to have in our material at the exact rate that we want it, to machine it at that same rate, and to assemble it and dispatch it so that the product itself forms a continuous stream from the moment the raw material enters the works until its final dispatch to the customer, but this ideal is rarely, if ever, achieved. To us who have to face the problem of a large number of types, small quantities to manufacture, and a quick delivery demanded, there is no alternative but a properly constituted stores or stock room in which we must carry certain components, the numbers of which will depend on either our monthly, quarterly, or yearly demand. Stores control will, therefore, demand of our production engineer all that is best in him, and even if he were a "Solomon" he would fail at times because of the uncertainty of the information that is given to him.

The Human Element.

It is the considered opinion of many that the most important problems that production engineers have to face are those which concern themselves with the study of human beings. There is no study more interesting, neither will any of our efforts yield a greater return than those where our thoughts are directed on human beings and their welfare. As production engineers, we know when we are treating steel that such material gives very definitely better results when treated under certain methods. We know too that the best of steel improperly treated will probably fail early in service. This is also true of the human material we have to handle to achieve our ends. From the point of view of humanity alone this human material should be treated well, but from the point of view of production, proper treatment will yield ample returns for any efforts we may spend in this direction.

Now the production engineer's thoughts must always be directed towards obtaining high efficiency, and in looking over his organisation with a view to seeing whether it is functioning efficiently he will find many points of similarity between the works organisation and a human being. Each is directed by a brain, and each, as it grows older, will acquire more experience and, normally, make fewer mistakes. There is, however, one great difference, and that is, that in the human being there is no possibility of replacing those working parts that fail to function 100 per cent., and, consequently, in our humans there is either a steady deterioration or a final complete breakdown that puts " finish to the chapter " so far as the human being is concerned. A firm or organisation, on the other hand, can replace each element—human or machine—as and when it fails to function at a high level, and, consequently, if the directing brain is still good high efficiency in an organisation can be achieved in spite of its age. But do we keep up this policy of replacement to the high level demanded ? Are we not inclined to say of a machine : " Oh ! its only ten years old ; it ought to last another fifteen years " ? Do we not too often, in thinking of our human tools and noticing that they appear to be over-burdened, pay too much attention to such things as length of service and past services ? I do not want you to think for one moment that I would belittle length of service or past services. I am all for recognising the value of both of these traits, but when the human beings begin to fall off in efficiency it is better to find them work with less responsibility than to let them drag along, perhaps holding back others, and, of necessity, lowering the vitality of the whole.

When we instal a crane we treat it entirely different from when we put a human being into our organisation. So far as the crane is concerned, we lay it down definitely that the load shall never exceed a certain amount. With human beings we are apt to treat

them in an entirely different way. We apply all the load they can carry, and we are apt to forget, I think, that a time may come when the human being cannot carry so great a load as he has previously borne.

As a consequence of this we may keep men far too long on their job, instead of replacing them by others more alert and able to maintain the high efficiency that modern conditions demand. In this connection we should always remember that when such a man is becoming inefficient we are doing him a real kindness by finding him work with less responsibility, and in this way we can take care of those characteristics of value which our experience has shown him to possess.

When, however, we are dealing with machines we have no such considerations to make. The only question that arises here is whether the machine is efficient enough for our purpose, and if the answer is in the negative, then a replacement is indicated. Age, however, must not be the basis used. It does not at all follow that when a machine is old it is inefficient. We have all had experience where a machine has become inefficient in quite a short time because new designs have already supplanted it. On the other hand, we have all been forced to use machinery that long ago should have reached the scrap-heap. I just mention machinery in this connection because it is intimately tied up with the human element, not necessarily the users, but quite often the human element in the organization that has to decide whether new plant shall be obtained, or not.

Here, then, under our heading of "The Human Element," we have a major function of the Production Engineer, that is, of keeping as perfect a balance as possible in the organization under his control, paying due regard to both personnel and equipment. So far as the human side is concerned, success or failure depend very largely on our production engineer's ability to create an atmosphere suitable to his needs.

A Correct Atmosphere.

In my opinion if we wish to get the maximum out of an organization we must see that our best efforts are expended in building up and maintaining a correct atmosphere in the organization itself. What we want, and what we must have, is clarity of vision and willingness on the part of the whole organization to do that which the planned scheme lays down shall be done. If we can get this correct atmosphere, then the whole of the working force will be moving at their best pace, and, more important still, in the desired direction. When we are driving a car we know what a great difference a fog will make in the time required to get to a certain place. Visibility is bad and direction is uncertain, and a bad atmosphere in an organization has the same slowing-down effect on the progress of

the work in a factory as does that of a fog when we are driving a car on the road. In my view then another vital function of the production engineer is to clear the vision of all concerned as to what are the intentions of the management, and to indicate concisely the directions that must be taken. It follows, too, of necessity that the effectiveness of this can only be obtained when the production engineer sees that all his plans are carried through to completion.

Conclusion.

From what has already been said, and from the multiplicity of functions outlined, it would appear that the production engineer needs to be almost a superman to deal with his many functions Personally, I have no belief in the superman, neither do I think that such a man, if he existed, is needed to carry out the various functions we have been discussing.

According to the organization to which he is attached, the production engineer will have a number of technical heads for each of the functions enumerated, and whether they are successful or not in carrying out their work will depend on the individual capacity of each subordinate, together with the coupling up of the whole of them into a properly balanced organization.

So far as the production engineer himself is concerned he must be a man of wide experience. He must have considerable knowledge of the details pertaining to each of the separate functions we have enumerated. He must, too, and this is particularly vital, have that capacity which shall keep each of these separate entities in his organization working steadily and to the best advantage, not for their own advantage, but that of the establishment as a whole. I mentioned experience because it will be largely from this that the production engineer will derive the schemes which he will have to put into force, and maintain, to keep each of his several sections functioning correctly. It must, however, be the right kind of experience, and, what is more vital still, that there is the correct mentality behind it.

Most of us know of men who have had so much experience that they can only remember the things that cannot be done. They seem totally to forget that the reason why some of these things could not be done was due to the circumstances surrounding the particular experience. In this connection we must never lose sight of the fact that what was not possible yesterday is possible to-day. We must always remember, too, that what does not appear possible to-day may be possible to-morrow when the circumstances have changed. This means—if it means anything—that whilst our production engineer must be a man of experience, he must also be a man with a breadth of vision and an analytic mind, a combination

which will tell him whether the failures of the past can, by a slight re-arrangement, be altered into the success of the futurees.

Above everything, he must be a leader ; a man who will be looked up to by his staff ; a man whose word can be relied upon. Such a man, with well-chosen subordinates, can go a long way towards making that success which is so highly desirable to us as production engineers.

Discussion, Edinburgh Section.

MR. KIRKWOOD : There is one thing I would like to stress, and that is the point made in the beginning of the Paper in regard to the contact with the production while it is still on the drawing board. That, I think, is very often overlooked. The production engineer is still far too apt to say that his responsibility does not start until he gets the finished blue-print. While production engineers are not always welcome in the first instance, I think that is more a matter of precedent than anything else, and it is up to us to break down that precedent, and I am sure there are many ways in which designers can be assisted.

Very often a designer may have two ways of doing a job, and it is a " toss-up " which way he takes. If the production engineer can say that one is difficult to work out in the shop, while the other is easier, then the designer is told and the final result is very much better.

Mr. Groocock's remark about the designers not being in touch with modern practice is, I am afraid, only too true, and we can hardly blame the designers because they are not kept in touch with practical problems. They work in two dimensions. We, unfortunately, in the shop, have to work in three. We have not to blame the designers for that lack. It is up to us to show that we can counteract this lack of knowledge by proper contact at the right stage.

MR. GROOCOCK : I am glad that Mr. Kirkwood agrees with me in respect of the necessity for the production engineer to get in touch with the design while it is still on the drawing board. I know there is a considerable difference of opinion on this question, but I do not think that the production engineer is going to be the complete success that he ought to be unless he acts as a missionary between shops and designers. The designer might probably think it was lowering to his dignity to come down to the shops for an opinion ! On the other hand, the production engineer might probably think that in approaching the designer he was putting an inch or two on his stature. Consequently, it is all in favour of the production engineer to act as a missionary in such cases.

MR. BENNET (Section President) : Mr. Groocock, which, in your opinion, are all the functions of the production engineer ? Where does the question of management come in ? Is there not a likelihood that in some shops the management are not quite sympathetic to interchange of opinions between production and design ? Is there not a risk that some production engineers really cannot approach the designers ? I think shop management has a

certain amount of say in the freedom with which designers and production engineers can get together.

Mr. Groocock: The functions of management are really the same as the functions of the production engineer that I have just been describing, except that possibly the manager has a few more functions tacked on. If the manager of a plant has not sufficient confidence in the production engineer being able to handle this question of suitability of design he should then deal with that side himself. If, on the other hand, the manager of a plant is not sufficiently free to deal with this side, then he should delegate the duty to his production man, or an assistant. There must not be a lot of people dealing with this matter. It must be the duty of only one man.

Mr. Wright (President, Glasgow Section): It may surprise some people to know what the functions of a production engineer really are, but after Mr. Groocock's explanation to-night, you may also wonder what he does with his spare time.

On this question of design I feel it necessary to say one word, and that is that whilst the production engineer can do a considerable amount by co-operating with the designer, I do not think this aspect should be overstressed, because a new design may not appeal to him in its proper perspective, in so far as he must always remember that probably a new design may also be a selling point, and in that respect he may not be well-informed, and, therefore, ideas he may have in his mind affecting methods of manufacture must not be allowed to weigh too much against a new design. That, of course, is my own personal opinion. The question of whether the manager should interfere with the production engineer all boils down to the question of making a profit. That is what a company exists for, and no intelligent manager would interfere with any function of a production engineer providing, by his action, he is aiming at that one common desire—the making of profit.

Mr. Groocock: Mr. Wright is quite correct in saying that the production engineer should not interfere with the designer. Such interference would be fatal and would work in the opposite direction from what I have in mind. In his contact with the designer the production engineer should not do or say anything which will "cramp" the designer's style, but when new designs do come along, if he sees them early enough, then he will be able to point out to the designer any difficulties in manufacture which will affect the price. As I have already pointed out, alterations can then be made, or different arrangements must come into force with regard to the price of manufacture. Such decisions have to be made rapidly, and if the production engineer can gain a week or two by seeing the design on the board, so much the better.

Mr. Brunton: I should be very interested to learn from Mr. Groocock just what type of young person trained along what lines, he thinks would make his best production engineer. In the mechanical engineering industry, you have three different types of trainee: the young man trained in the shops, going straight from school to shop work, and gaining some technical training in the evening schools; then you have the young man who goes into the drawing office after a short works training; and, finally, the more fortunate individual, from a financial point of view, the university or college trained young man, who gains shop experience during and after his training in technical matters. The position seems to demand a very great amount of shop experience, but at the same time, it demands a thorough appreciation of the technical points in machine design, in power transmission, in the choice of electric motors, etc., in short, a good technical knowledge, that is not always possessed by the practical man. I should be interested to learn, in brief, what Mr. Groocock considers the ideal course of training for a young man proposing to fit himself for the position of production engineer.

Mr. Groocock: It would be difficult in the time at my disposal to deal adequately with the questions raised by Mr. Brunton. With regard to the necessary training of a production engineer, I cannot do better than refer Mr. Brunton to the syllabus got out by our Institution for the training of graduates who are to sit for the graduates' examination. If he looks over the series of questions asked in these examination papers he will find that they are practically covered regularly by lectures at our various sections. Our Institution has for some years been collaborating with the heads of various technical institutions, and we have had the greatest of help from this close co-ordination of the teaching and productive side. You Edinburgh people need fear no one on the technical side, and if production courses can be put in here you will have no trouble in finding young men with shop experience who can take the necessary technical training to qualify them, by a combination of the two, for graduate membership of our Institution. We, as an Institution, are paying particular attention to the graduate side, because the graduates of to-day will be the production engineers of the future.

Technical education, highly desirable as it is, however, is not the only qualification necessary. One of the difficulties that have been found with the college-trained man is that there has been something left out of his training. Too often the acquirement of a degree is considered the end, instead of the means to an end. While a toolmaker may have a micrometer, or a seaman a sextant, until they can use those instruments in their business they are of little value to them. Technical education, therefore, must be regarded as a tool, and until we can use it it is of little use to ourselves or to

the community. So far as college-trained men are concerned, they appear to be at a disadvantage on the production side. What too many college-trained men lack is really " time sense," and a man with no " time sense " will be a failure on the productive side. My own experience has shown that boys who work all day in the shop and after hours are willing to attend evening classes are much more in touch with realities than university graduates. This, I consider, is rather a weak point in the training received at universities, considered from the viewpoint of production engineering, and steps should be taken to remedy this weakness.

MR. ADAM : I have listened with great interest to Mr. Groocock's paper. Whilst I was listening a thought passed through my mind, I agree with everything in the paper—it is all common sense. I wondered what the real value of the paper was, and I think it lies mainly in that it is a great thing to put these things in front of people in black and white. Regarding the question that Mr. Brunton raised, it struck me that one of the chief qualifications is just plain " horse sense," and the way a young man can best qualify himself for some of these executive posts is to be a " nosey parker," to go around trying to pick up as much information as he can, and as much experience as he can.

MR. GROOCOCK : I agree entirely with your last remark. If we want to be a success as an engineer we must be a " nosey parker," that is, we must be inquisitive and definitely find an answer to those things in our mind where no answer is present. We must not be satisfied with the general idea, but must get to the bottom of things. The " nosey parker " that you refer to merely shows that he is possessed of initiative, and those boys who are merely satisfied to work machines may make good craftsmen and stop at that, but the boy with initiative will go to a technical school to find the answer to those many questions that arise in his mind. He may not be very clever, but he will get the necessary experience, and in training himself up on the technical side at the same time that he is being trained in the workshop he will acquire the proper mentality for branching out into a production engineer.

MR. CORBORTON : Most of the discussion has been around production engineering and designing to begin with. In the States it seems to be that the production side co-operates with the sales side in preference to designing. Don't you think it is the duty of the production engineer to co-operate with the sales as much as possible, and to try and help the men on the road actually selling the material? You have to rely on the man on the road to get orders for shops. Unless the man on the road is helped by the production engineer, you won't get orders that you want.

MR. GROOCOCK : Mr. Corborton has taken production engineering a little further than I would be prepared to go. I do not mean to

suggest that I would separate entirely the production engineer from sales, because, as a matter of fact, I personally, have close contact with our own sales organisation. Either the production engineer or the works manager must, of necessity, get from the sales organisation an expression of opinion as to what their sales in future will be. Unless this is done there can be no manufacturing programme. There must, therefore, be some contact in this respect, but in my opinion the main contact between sales and works must be through the works manager.

Mr. Gilhooley: For all your explanation, sir, of the functions of a production engineer—a 100 per cent. practical man or a 100 per cent. technical man—I suggest the combination cannot be obtained in one person. Then to what side, practical or technical, must the production engineer incline? As a practical man must devote himself to shop work to become really expert, it may be that he is lacking in sufficient technical knowledge to be able to criticise the design, etc., from a technical standpoint, yet it seems, from the speaker's definition, that if he is a production engineer it is part of his function to do so. But is it not, however, the essentially practical man who makes the best production engineer? Who is then, in the speaker's mind, the ideal production engineer?

Mr. Groocock: One hundred per cent. efficiency is always difficult to obtain. So far as the production engineer is concerned, the point that I have stressed is the need for the production engineer himself to see that he has a proper balance in his organisation. In this proper balance he will have good technical men and good practical men. He will have, too, a combination of both these sides in various degrees. The ideal production engineer would be a man who went into an organisation and with the tools at his disposal—both human and material—could "devise ways and means to increase the productivity of that particular plant," and, having achieved this would then repeat the process ad infinitum. The production engineer should not criticise the designs, as such. He should be able to point out to the designer those parts that will be difficult to make—and why they are difficult to make with the existing plant. This is the time then to make suggestions that will make things easier for production in the shops.

Mr. Burns: The question raised by Mr. Brunton is a very important one for an inaugural meeting such as this. Following the lecturer's definition of the duties of a production engineer, I am rather inclined to the view that "Production Organiser" might be regarded as a more correct description. The production organiser has to be able to adapt himself to the various difficulties of the factory, most of which may be unrelated to actual engineering technique. At the same time it must be accepted that the initial training as engineer is an absolute necessity for the position,

although, unless a man has the faculty in him for development, he will never make a good organiser or "production engineer." I have, personally, had experience with an American firm where the production engineer or supervisor is the 100 per cent. efficiency organiser. Before closing, I should like to refer to a matter concerning costs which occurred to me during Mr. Groocock's lecture. By reducing labour cost it does not follow that economy has been effected. By changing an operation from, say, a £200 machine to a £1,500 machine it might be possible to reduce labour costs by 50 per cent., but due to the larger overheads incurred, in addition to heavier depreciation expense, the wages saved might easily be outweighed. This is an instance of where the production engineer requires to have a good grounding in costs and overheads.

Mr. Groocock: Yes, it is quite true, a production engineer must have organising ability, because unless he has this he cannot get the number of people whom he controls working to a common end. Organising ability, however, is not the only thing, because over and over again we find organising ability that cannot be pushed to completion simply because the organiser lacks just that quality of leadership that is necessary to "weld" the organisation into a unit. The other question raised by Mr. Burns about overheads is important, and I know it is sometimes difficult for production engineers to realise fully, not only what overheads mean, but how big an influence they have on costs. The production engineer who expects to get anywhere in life must have a very close acquaintance with all factors that affect his problem, and overheads is one of these factors.

Dr. Muir: Mr. Adam suggested that what he called common sense was one thing which was a big factor in the training of the production engineer. It is a well-known fact that the intelligence reaches its maximum point about the ages of sixteen or seventeen. After that what is acquired is something different from general intelligence. It is the accumulation of knowledge. If you could test people who are entering professions of various kinds and find those with high intelligence, you would be able to select earlier the people who would probably go far in production engineering. It would not be difficult to work in that way, because we have in this country an institution called the National Institute of Industrial Psychology which has done a tremendous lot of work in this connection. There are very satisfactory tests for finding out the characteristics which were mentioned as necessary in a production engineer. I, consequently, feel that if selection were made early of persons with high intelligence factors, they could be trained practically, and then placed in the proper channels for obtaining the necessary technical training in evening classes. Such training and

selection, directed along proper lines, would be helpful in producing very efficient production engineers.

MR. GROOCOCK: Dr. Muir has put his finger on a particularly good point. Unfortunately, we have not been able to do much with psychology in the works, except in one or two of the larger organisations where psychology has been employed with a view to finding out what certain of the younger employees were suitable for. While I do not think that so far as the average works are concerned psychology has got to the point where it could help us to any considerable extent, I do definitely feel that there is a big field in this respect at the colleges themselves, and particularly at the universities. Here it would be possible to definitely determine whether a man who is being trained as an engineer would be suitable for either design, research, or for the productive side of the industry, and if this were done I have a definite feeling that we should not have so many "mis-fits" from universities as have been found by past experience. Engineering should really be a science. At the moment it is nothing but an art, and the production engineer may be likened to an artist. The artist visualises a picture and brings it into being by the use of certain pigments; the production engineer also visualises a "picture" but many of the materials that he would like to use are absent, and, consequently, he has to paint his "picture" according to what materials he has for use. In other words, the plans he makes depends on the conditions under which he has to produce. It depends very largely too on his experience of using his various materials. At the present moment I think it would be true to say that the strongest side of the majority of production engineers to-day is experience, and this cannot be reduced to a formula.

THE CHAIRMAN (MR. BENNET): Well, gentlemen, I do not feel competent to sum up the conclusions Mr. Groocock has put before us and the discussions that have emerged from the members. It is quite obvious that, as Mr. Groocock says, the subject cannot be handled with one paper. He has most admirably sketched the main outlines and has most patiently replied to our questions. I am very proud indeed that it was my suggestion that Mr. Groocock be our first lecturer, because he has put up a big problem for us to think over before our next meeting, and I would ask you, gentlemen, to propose a very hearty vote of thanks to Mr. Groocock for his goodness in coming here.

Discussion, Luton Section.

In the absence of Mr. Groocock, his Paper was read by Mr. W. Stancliffe Marsden, Institution Staff.

Mr. R. W. Bedford (Chairman) said that he thought all would agree that they had listened to a very instructive and interesting paper, admirably read by Mr. Marsden. They were fortunate in knowing Mr. Groocock, who had already paid one visit to Luton, and they hoped that he would soon come again. In the absence of Mr. Groocock, they would have to get the author's point of view in writing and he considered, therefore, that any discussion should be more or less constructive criticisms and an interchange of views. He expressed their thanks to Mr. Hazleton, the General Secretary who was present at the meeting, for arranging for this splendid paper to be read at such short notice, bearing in mind that this was substituted for another paper, the author of whom had been taken ill.

Mr. Bamford said he quite realised that the activities of a production engineer covered a very wide range, but no mention had been made in the paper as regards the control of the layout of a factory. This seemed to be a very important point, because if a production engineer is to be responsible for the purchase and installation of machinery and equipment, he should have some knowledge of the construction of the factory in which such equipment is to be installed.

Mr. Bedford replied that it had been gathered from Mr. Groocock's paper that one of the duties of the production engineer should be to control the purchase and layout of all plant. He agreed that it was very essential for a production engineer to control the layout of the plant, not only the layout, but also the choosing of the right type of machinery required for any particular commodity to be produced. There was one further point he would like to raise. That was the question of a production engineer not only having knowledge of estimating, but also being able to keep a check on the estimated cost as the work passed through the factory, so that on completion of the job, he was not faced with a loss instead of the estimated profit.

Members had had an opportunity of reading Sir Walter Kent's address given in Glasgow, outlining a scheme which is at present in operation with his company. Under that scheme, the head of the department concerned was called into conference at the time the job was estimated, and he had to give certain production times. If such estimated times were too high, then it was for the works

manager to step in and insist on these figures being reduced. In any case, the estimate was based very largely upon the co-operation of the heads of the estimating and producing departments concerned. When the estimated job became an actual order, departmental orders were placed, which gave the department or departments concerned a "credit" which agreed with the estimated times already submitted.

The cost office keep a careful check on the cost of the job, and contact was made at least once a week with the head of the producing department concerned, and if it was found that production costs have exceeded the estimate, then it was up to the head of the department concerned to see if it was possible either to improve his layout or machining methods, or carry out improvements in any other possible direction in an endeavour to keep the cost of the order within the estimated cost.

Mr. Larsson, referring to Mr. Bedford's remarks regarding the system of estimating, wondered if there was a danger of the departmental foreman including in his estimated times sufficient to make sure that he covered himself. There must obviously be a very strong check on this point in the estimating department, even though, as pointed out in Mr. Groocock's paper, there must be full co-operation between the foremen and estimators. Was it not natural that the foreman would cover himself, and for that reason urge the estimating department to accept some figures which may be excessive?

Mr. Bedford agreed that there was, of course, that danger, but it was usually safeguarded by the fact that the estimating department were in a position to also refer to similar work which had already been carried out. When it was a question of a series of operations or processes which were very much alike, it was purely a question of time, and the estimating department could usually see at a glance whether the foreman had claimed too much time for the particular job he had to do. It was, however, a point which does want watching, although he did not think there were many instances of a shop foreman deliberately claiming too much time in an endeavour to safeguard himself.

Mr. Pudge stated that Mr. Groocock had not mentioned in his paper how the oncosts are arrived at, and he considered this a very important point, because these oncosts would probably vary considerably from one department to another.

Mr. Bedford agreed that Mr. Groocock had not mentioned this point. He had, however, mentioned that the production engineer must keep a very careful check on tool costs, maintenance costs, and other things relating to actual production costs, even though the labour times may be correct.

Mr. Carlton-Smith said that he would like to preface his remarks by paying a tribute to the very masterful paper presented.

Referring to Mr. Bamford's remarks in connection with the question of plant layout, he considered that Mr. Groocock had covered that point. He thought there were many points to be considered in planning the layout of a factory. For instance, if production was sufficient to warrant a line of continuously running machinery, then the production engineer would take steps to obtain the best possible plant for the job. Occasionally, however, there are other considerations. For instance, for the purpose of meeting, say, a three years' contract, it might be decided to instal a machine such as a 24-spindle machine, which, after completion of the contract referred to, would probably only be required for one hour per day. Then again, it might be considered desirable to instal some hydraulic equipment, but at the same time, it might be that in three years this equipment would probably be replaced by electrical equipment, in which case the depreciation on the outlay would be rather excessive. This meant being often faced with the problem of putting in a plant which one knew was not quite so productive as some, but on the other hand, not so expensive, but fully capable of meeting requirements.

He agreed with almost everything in the paper. One exception, however, was the question of the designer. He considered that if the designer was not a production engineer, then he had no right to be a designer. In one or two cases, however, such as a designer who produced models in wood or plaster, that man—as a designer, was also a production engineer.

Mr. Bamford stated that apparently Mr. Carlton-Smith had not interpreted his remarks as regards the layout of a factory in the manner in which they had been intended. It would not be much use a production engineer being responsible for the purchase and installation of a large press unless he had sufficient knowledge of the construction of the floor and roof trusses. He must have a constructional knowledge of all areas throughout the factory, and be in position to advise upon the installation of any plant, bearing in mind the operating of such plant in conjunction with other machinery, as when it came to a question of installing a variety of machinery in any one particular area, the construction of the floor was a very important factor.

Mr. Hazleton stated that, as General Secretary, he probably approached the considerations of the subject of this paper from a very different angle to most of those present. The paper had been written by Mr. Groocock at his (Mr. Hazleton's) suggestion, for delivery before two of our new local sections, namely Edinburgh and Leicester. The primary object of the paper had been to give their new sections an idea of the functions and the scope of work

of a production engineer, and he regarded it as a very valuable contribution to their Proceedings.

The Council was at present engaged in considering the scope of Institution membership. Mr. Ronald, in his Presidential address last year, also dealt with this question, and the more it was examined, the more difficult it was found to be to define exactly the term "Production Engineer." Many people had attempted definitions and it seemed that a more useful purpose would be served, not by attempting definitions, but rather by analysing functions. If you analyse functions sufficiently to cover the whole ground of what a production engineer does, this should help considerably in coming to a right conclusion as regards the scope of membership of the Institution.

MR. BEDFORD said that Mr. Hazleton had certainly described Mr. Groocock's intention very well indeed. Mr. Bedford considered that Mr. Groocock had described the ideal production engineer; he did not know whether any of them actually possessed all the qualifications referred to in the paper, but he hoped that they all aspired to have these qualities, and also the facilities for carrying them out. Certain firms did purchase material, control their stores, and also carry out their designs, in "water-tight" compartments, but it was certainly nearer the ideal for the production engineer to be so closely related to them that he could influence and assist the organisation as a whole.

MR. BAINES said that after listening to the paper, he wondered what a production engineer did in his spare time. One question he would like to raise was the shortage of skilled labour to-day. This was presenting quite a problem. It was very difficult to forecast the cost of work, inasmuch as it might be necessary to take on inferior labour, and on some machine operations, it might mean two men working one machine for a period, until those men become more familiar with the operation they have to perform. That must add to the cost, also the overheads. Another important point was that in some cases, after receipt of the order, a long time was taken in the drawing office before the necessary information reached the shop. That might mean the shops eventually working overtime in order to meet the date of completion, or that they might even resort to a departure from the planning operations, using other machinery and equipment, which might not actually be for the best when all things were considered. Under such conditions it appeared to be very difficult indeed for a production engineer accurately to forecast the cost of the job.

MR. BEDFORD considered that Mr. Baines had touched upon a problem which was very acute in the South, where there was a real shortage of skilled labour, and it did not seem as if the problem was going to be solved by immigration of people from other areas.

It looked as if the production engineer would have to add to his many duties, not to organise a system of training, but to influence the heads of his organisation to see that various sections of the works are fitted up to train labour—if it is impossible to obtain that training in technical colleges or by apprenticeship schemes—by having some sort of shop set apart where operators would be trained in the functioning of the various machines until they can operate them at reasonable production times ; this would enable an operator to keep within the estimate, without probably smashing up a machine perhaps costing several hundred pounds, the first time he gets on to it. This was a problem which would definitely have to be dealt with in the very near future. The Government had made a step in this direction by putting up training centres, where men received some sort of training which fits them to become operators or semi-skilled men in their particular job, but that scheme wants multiplying many times over to be of any real use in modern engineering production.

Mr. Bullock stated that in his opinion the shortage of skilled labour would continue until they were able to offer the type of reward to merit the amount of training which is required, as at the moment he considered engineering to be one of the worst paid trades in the world.

Mr. Pudge did not agree that the question of obtaining skilled labour was nearly so acute as they were led to believe.

Mr. Ault referred to the fact that one speaker wondered what a production engineer did in his spare time, but it would appear that such officials as the general manager and works manager will have all spare time if the production engineer goes on as he is at present. He agreed with Mr. Groocock's paper in its entirety, but if a production engineer must possess all those qualities referred to in the paper, then obviously one man could never hope to live long enough to become an efficient production engineer.

One point of particular interest was the reference made by Mr. Groocock to the danger of material coming in too soon ; surely, all those present at the meeting had had many experiences of material coming in too late, and he certainly could not accept the premature arrival of raw material as a " danger." Also, in this connection, was the question of price. There were many instances where material could be purchased more cheaply if ordered, say, a fortnight earlier than actually required. This would often outweigh the disadvantage of having capital tied up in material stock which cannot be used immediately.

With regard to the question of design, production planning, progressing, etc., being related, generally the designing was carried out by an almost water-tight compartment, from whence one got the impression that " We have done the designing—the rest is up

to you." Another point of interest was the question of various shop foremen over-estimating for their own safety. His experience had been the reverse ; the average honest foreman cuts his estimate so fine that he often does himself harm, and there was definitely a likelihood of the boot being on the other foot.

MR. BEDFORD stated that on considering this paper, there was a distinct possibility that the production engineer, in the modern trend of engineering production, would usurp the position of works manager, resulting in the title of " works manager " dropping into disuse. With regard to getting material in too soon, perhaps Mr. Ault had not been called over the coals as some of them had. One sometimes insisted on getting material along in good time in order to have a good reserve, but on receipt of the invoice, one was faced with such challenges as " We have this material to pay for, and the job is not due to be started yet." That was a point to be borne in mind. You could not have the material without paying for it, and that would often mean capital lying idle. He agreed with Mr. Ault's view as regards co-operation between the production engineer and the progress-man. Only too often does the progress-man ask for completion a month ahead of actual requirements, and with other jobs going through at the same time, this might lead to dislocation. It was obviously preferable for a production engineer to be in a position to see that no other jobs were inserted into a programme unless the original date had been put back. Under such conditions, the production engineer should control the progress department.

MR. RONALD (Section President), said he would like to thank Mr. Bedford for presiding at this meeting on account of his (Mr. Ronald's) indisposition. With regard to the paper itself, he was in complete agreement ; there were several points he would have liked to have discussed, had circumstances rendered it more convenient.

MR. BEDFORD closed the meeting by proposing a hearty vote of thanks to Mr. Groocock for his paper, and also to Mr. Marsden for the admirable manner in which he had presented it to them that evening in Mr. Groocock's absence.

WRITTEN REPLIES BY MR. GROOCOCK.

Although I was not able to read the paper before the Luton Section, owing to the short notice, I have been asked to reply to one or two points that arose in the discussion.

In the first place I would like to say that Mr. Bedford, who was in the chair, answered quite a number of the points that I would, had I read the paper, have normally have had to answer, and it is astonishing to find how near in his answers he has come to my idea of what those answers should have been. I want to place it on record how much I appreciate Mr. Bedford's efforts in this direction. With regard to the discussion as a whole, I think it will serve a useful purpose, but I do not propose to go over the discussion in its entirety but to deal with a few of the outstanding points that do not appear to have been covered in the discussions at Edinburgh and Leicester.

Layout of Factory.—This point was raised by Mr. Bamford. Generally speaking, the production engineer does not have much concern with layout of factory as this is, in my estimation, a managerial concern.

Obviously, the layout must be such that it will be suitable to the average condition of manufacture. Clearly, however, there may be special cases where " bottle necks " will arise, and this was mentioned in the original paper—that the production engineer must be ever alive to the possibility of such " bottle necks " occurring. The steps that will be taken to overcome them will depend on the organisation, but whenever they occur it is up to the production engineer to see that the position is remedied so that he can get his work through in time and at an economical price.

Oncosts.—This was a point raised by Mr. Pudge. Apparently Mr. Pudge would like the production engineer to know how oncosts are arrived at. My own view is that while the production engineer may be interested in the building up of the oncosts as a whole he is only concerned, as a production engineer, in the effect of those oncosts on the labour that he is using. If in spreading the oncosts there is a different ratio for different departments, then certainly he should know what it is, but my own view is, as stated, that as a production engineer he has only an academical interest in the building up of the oncosts. That is a managerial proposition which he should know something of as it may come under the functions that he will have to deal with when he goes to another job higher up.

The Purpose of Paper.—Mr. Hazleton outlined, I think, what was behind the paper itself, and it is clear from the general discussions

that have taken place at three different centres that there is a growing need for some clearly-defined list of functions which do, of necessity, come under the general heading of production engineering.

Quite clearly, in the paper, many points were raised with a view to getting the opinions of members, and a consideration of the full discussion will show that this side of the paper was at least achieved.

It is felt by myself that with the discussion in front of us we shall have a more definite idea of these functions than we had before the paper was given.

The Ideal Production Engineer.—Mr. Bedford, in the many excellent things that he said in the discussion, mentioned that in writing the paper I had the ideal production engineer in mind. This is so. Just how near we can approach this ideal, or, alternatively, just how near we are allowed to approach this ideal, is a question of how far we can go if permitted, and how far we would be permitted to go if we had the capacity.

In outlining a list of functions we must, of necessity, outline the ideal so far as we can see it.

There was not a single item mentioned in the paper that is not being controlled by one or other of our members—working from the graduates to our senior members—and there is a number of our members who actually control quite a large number of these functions themselves. Clearly, however, they have others to help them.

When we speak of the functions of a production engineer we are speaking rather of the functions over which he has control than of those with which he actually deals himself.

My view is that any of the assistants who are helping the production engineer to carry out these various functions are available as members of this Institution if they can fulfil the primary condition, that is, that they are trained engineers and are engaged in some section of production engineering.

Spare Time.—The question of what the production engineer does with his spare time is an interesting one, but, quite frankly, such a man, if he lives up to my estimation of him, would have no spare time. When he finds his load is too heavy in one direction he gets an assistant; when he finds that he has spare time, then he uses that spare time to see that all his various assistants are working as nearly one hundred per cent. as he could expect them to.

The question, too, was raised as to whether life was long enough to ever become an efficient production engineer. That is doubtful, but we start in a junior position as a production engineer, say, a graduate; we progress until our status is improved and we are then an associate member; finally we progress to the point where we can become a full member of our Institution, but I venture to think

that in the higher grades of our Institution there are many who may be termed efficient production engineers. There are few, I think, however, who would mark themselves one hundred per cent. efficient. What is efficiency, anyway ? The efficient of to-day may be the inefficient of to-morrow unless he keeps himself au fait with current conditions in his profession.

Skilled Labour.—While the question of skilled labour, or the training of skilled labour, is outside the scope of this paper it should be said that production engineers can do much in this respect by using a little of their spare time to look ahead and see how much training of skilled labour they can bring about. It is just possible that this question of skilled labour is, shall I say, a managerial function, but every time the production engineer is np against it on the question of availability of skilled labour he should impress this on the management in such a way that they will take steps themselves to do a little bit in the training of skilled labour, rather than leave it all to someone else, say, a Government Department—as was suggested. The old saying "The Lord helps them that help themselves" still stands good and is particularly applicable to the provision of skilled labour.

Material.—The question of material coming in too soon, mentioned in the original paper, obviously had reference to material for any special job, and it is a waste of time to have such material in too early.

When we are dealing with that class of material which we normally stock, if we are doing our job right, that will be purchased in the cheapest market and at times most suitable (1) to our own requirements, and (2) the price at which it can be purchased.

Co-operation.—One point was raised, namely, that there should be full co-operation between the production engineer and the progress man.

Whilst I agree to the fullest kind of co-operation, my own view is that the production engineer should dominate the situation and that the progress man should carry out the orders and the times laid down by the production engineer. There is not any question at all that the progression of work through a shop is almost solely a clerical job, and there is a large number of progress people who are definitely not eligible for membership of our Institution. It would appear, therefore, that to ask for co-operation between the progress man and the production engineer is "putting the cart before the horse." The line of policy should be laid down by the production engineer and the progress man should carry that policy out.

In conclusion, I would like to thank Mr. Marsden for stepping into the breach and reading the paper at Luton.

Discussion, Leicester Section.

MR. GROOCOCK (replying to the Section President, Mr. Hallam): In the opening by your President, he mentioned three points which need some comment from me. In the first place he emphasised the point that no matter what we were doing our one aim as production engineers should be to attempt to produce more and better goods from the factory we were connected with. It might well be that such a factory was not at all up-to-date; it might have poor equipment; but if the production engineer has got the right ideas, then he can always be doing something which will improve the quality and the quantity of the output. The second point that your chairman raised was that before tools and jigs left the toolroom they ought to be tried out, and I agree with him entirely that such trial productions should take place in the toolroom as far as that is possible, but there are many cases where special tools made for capstan lathes or automatics can only be tried out in the machine shop itself, and it is there that we get full value from good foremanship, if such is available. In the paper itself I expressed my views very clearly on the value of good foremanship as I maintain that the foreman himself has a large responsibility on the production side, more particularly in those factories where the quantity factor is not high. The last point raised by your President was the question of the smaller shop being unable to afford a planning department. As I mentioned in the paper, whether we have a planning department or not, planning in some form or other must take place, and as an illustration of what can be done in the small works let me give the methods in one small works that comes under my knowledge. When a new device has to be made, as soon as the designs come out the works manager calls into conference on these designs the production manager, the head foreman of the machine shop, the chief ratefixer, and the toolroom foreman, and at this conference they decide just what operations are necessary, the sequence of the operations, and the tools that are required. From this conference, which may last two hours or more, a plan is evolved. The toolroom foreman makes out operation lists, the jigs and tools required are all listed against operations, and, consequently, although this particular factory has no planning department as such, they have gone through all the motions that would be gone through in the larger organisation by an established planning department. I suggest, therefore, to those who are connected with the small factories that such a method, with modifications to suit, could be run, and they would then have all the advantages of pre-planning.

Mr. Bray : I came here this evening hoping that in listening to a paper on " The Functions of the Production Engineer " I should find out what a production engineer really was, but what the lecturer has really outlined is what the production engineer—the senior production engineer—of any one factory has to do. Now that ties the name of production engineer down to one sphere in each factory. It is obvious that this Institution cannot be composed entirely of people who are just the senior production engineer of each factory, and it seems to my mind that a production engineer must be a more general title. You can have a number of mechanical engineers in your factory, but it would seem that there can be only one production engineer, and I should like to hear something of the functions of the junior production engineer. Personally, I am on the side which has been referred to as the designing side, and I was very interested in what the speaker had to say regarding the collaboration between the production side and the designing side. I do not entirely agree with him. The reason why I do not agree is that we have been looking at production too much as a whole when really, in this particular case, we have got to sub-divide it. I think we can sub-divide production into three general types—joint production, batch production, and mass production. Joint production is for a factory where we have one of the drawings and that is a contract of some special kind. Batch production I would call those cases where we have things going through the factory in batches of 50 to 100, etc. Mass production is when we have such places as our motor car works where they are on the same thing day after day—perhaps six months at a time, and the production engineer has rather different functions in each case. This point about collaboration between the production engineer and the designing side has, I think, an important relation to the type of production.

There is another point which I should like to raise on one of the things mentioned in the paper and, again, this is about the collaboration of the designer and the production engineer. In dealing with this Mr. Groocock said, " On the other hand, the designer himself will be able to impart some of his enthusiasm for his design to the production engineer, thus ensuring that those little things in the design which do not always appear on the drawing will receive full attention." I must protest against that sentence because I maintain that if you are going to have anything in the way of efficient production a part must be made to perfection from the drawings without any verbal contact at all. It might be all right in a very small shop. You might be able to say " We want a flat here and a screw thread there," but whenever you get anything like the mass production I maintain that is impossible, and I suggest that that sentence should have been left out, except, as I say, in certain cases—in very small factories.

Again about the stores control: This production engineer whom we have had pictured to us to-night seems to have grasped into his sphere of control a number of things which, I think, he ought not to try and control, and one of these is stores control. The lecturer said that the production engineer should control the number of finished articles in the stores as well as raw material. Now, providing you grant the production engineer the privilege of buying the material, which I think is quite reasonable although I believe not regularly done, certainly he must control the material in the stores, but I cannot see how the production engineer can control the finished articles in the stores—that depends on the commercial side of the business.

MR. GROOCOCK: It is quite obvious that Mr. Bray has not realised that in outlining the functions of the production engineer an attempt had been made to cover these functions as fully as possible. Mr. Bray seems to realise that we may have in a factory a number of mechanical engineers who, obviously, would be graded from senior down to junior, and yet he fails to realise that the same condition may and does exist with regard to the production engineer. If Mr. Bray were to attempt to outline the functions of a mechanical engineer he would find the same sort of conditions would exist. We do have in various organisations Members, Associate Members, and Graduates. As an instance of what I mean, I know of one small factory where the works manager is a Member of our Institution; the production manager is also a Member; and going further down the scale the man in charge of purchase and layout of plant is an Associate Member and one of his assistants is a Graduate Member. You will see, there, that in one small organisation there has been found scope for the work of each of the grades of our Institution.

As an Institution we are paying a good deal of attention to our Graduates. We realised years ago that we should not get very far unless we started a Graduate Section. This has been done and during the progress so far, with the assistance of the teaching profession, we have got out a thoroughly good syllabus for the examination, and many young men are taking this examination and entering the Institution as Graduates. Quite obviously, for some years after entering as Graduates these juniors do not occupy anything but a junior position, but they are, all of them, taking part in, and working at one of the functions that have already been mentioned in the paper itself. Later on, the position of these Graduates in the various firms will be improved and they will then become Associate Members when they reach a certain standard, or status, and so on to full Membership.

Mr. Bray has given his opinion that the collaboration spoken about in the paper would be different in the case of those firms making single articles or small quantity manufacture, and thus

increasing from this until we get the firm with mass production, that is, continuous production. I venture to think that Mr. Bray has not fully explored this point. Under each of these conditions of manufacture someone has to carry out all those functions that I have mentioned. Now Mr. Bray took me to task about the collaboration with the designing engineer and he said (and in this respect I am inclined to agree with him) that the production engineer could not spare too much time with the designers in the case of single piece manufacture. I want, however, to point out to Mr. Bray that if that single piece manufacture does result in a lot of scrap, simply because the designs have been made in such a way that it is going to be difficult to produce those pieces in the shop on existing machines, then I do say that the production engineer must spend some time in pointing out the difficulties to be met to the designing side. I do not mean to imply at all that there should be any interference between the production engineer and the designing engineer ; that would spoil the whole idea that I have in mind. There should, however, be co-ordinated collaboration between them, and in such a case as has been mentioned the production engineer should tell the design side that these difficulties will be met. A knowledge of the design side extending over a good number of years tells me that the designers do appreciate the shop point of view in such cases when the point of view is properly presented.

Mr. Bray seems to think that in the case of single piece manufacture it is perfection that has to be aimed at, but all of us who have an extended knowledge of this kind of manufacture know that the drawings for single piece manufacture are generally very incomplete as regards many of the details, such as tolerances, clearances, etc. It is on points like this that collaboration between works and design is so useful to an establishment. The other point that Mr. Bray brought up was stores control. The point he raised was that finished part stores control should come under the commercial department. Well, I have had considerable experience with commercial departments and know how difficult it is to get from them a real estimate of what we shall have to produce in the future. Generally speaking, in those firms making a number of apparatus' varying in size which are demanded at short notice, then I feel satisfied that the control of the details, that is, the finished details that go to make up such apparatus, must be in the hands of the production engineer. He keeps his stock then in such a way that he has reserve parts behind him to meet those emergencies which his previous sales show he will have to meet, or, alternatively, to meet those contingencies outlined in a forecast made either by himself or by the commercial department. It is not a case altogether of stocking finished pieces of apparatus—this definitely should be a commercial department's control—it is in the keeping of a certain

number of parts of finished material in the stores which would allow the production engineer to make his various pieces of apparatus in the shortest possible time.

Mr. Austin : I feel inclined to agree with Mr. Bray that more designers should have shop experience and if this were a fact, then the production engineer would not have to visit the drawing office quite so often. There are always two or more ways of getting a piece of work done in any particular factory, and quite possibly, any one of these ways may be the most efficient both from the point of view of production and of design. If this is so, then collaboration would point to the best way of doing the job, having regard to the machinery available. Mr. Groocock, in the course of his paper on the production engineer and his functions, did not seem to leave much for the works manager to do. I would like to have from Mr. Groocock an expression on this point. Another thing with which I did not agree was that Mr. Groocock appeared to favour having an electrical engineer as the head or senior man of our maintenance gang. Machine tools are getting more elaborate, and I certainly think that the leader of a maintenance gang of an ordinary machine shop should be a machine tool man.

Mr. Groocock : Mr. Austin, in his first few sentences, really said what I had in mind—that the designer too often has not sufficient knowledge of shop processes. What I am really asking for is that the production engineer should act as a missionary in this respect and should supply just that knowledge of workshop processes which the designers too often lack. If there is co-operation, as I expect there to be, then I am quite satisfied that it will work well. There is a difficulty, however, in some works of introducing this collaboration. There are places where it is below the dignity of the designer to go into the shop. There are places too where he is almost forbidden to go in the shop. On the other hand, we know of works where it is below the dignity of the production engineer to go into the drawing office, and again, perhaps this may be due to the fact that he is not welcome there. These attitudes of mind are entirely wrong because you cannot get really good team work unless these two essential services—design and production—are working together.

Mr. Austin wants to know what the works manager has to do. Generally speaking, a works manager is also a production engineer, and quite a few of the functions that have been outlined in the paper are really under the control of the works manager himself. Apart from this, the works manager's point of view is a broad one. He has to look at the organisation as a whole and see clearly every detail of the work—not necessarily do it. Generally speaking, the largest amount of a works manager's time goes to seeing that

there is closeness of co-operation between the many sections that make up his organisation.

With regard to Mr. Austin's other point, I do not think that I would, personally, make the electrician the senior on the maintenance force. I believe that the mechanical man will always be the best head to run a maintenance force because in the majority of cases it is the machine itself that is the most complicated. I raised the point about the importance of the electrical side because there is an ever-growing tendency for the use of more electrical appliances, not only on machine tools but electric ovens, control gears, and many other things, which do make it necessary that a first-class electrical man should be attached to the maintenance force.

MR. MADDOCK : Will Mr. Groocock tell us whether he has had experience of the trial production method, such as, when tools are made, a sort of semi-production department is set up and a quantity of the product put through to test out the tools and also to set times, etc., for fixing piecework prices. How does he find that such results work out when they are actually put into production in the works ? For instance, a motor car manufacturer is going to make 10,000 sets of parts of a certain shape or size, and after the tools are made, but before being put into the works, they are put into a separate department and 100 sets made and piecework rates and speeds, etc., are set. Can he tell us anything as to how these conditions work out in production when they get into the works, that is, when the real quantity for production is put in ?

MR. GROOCOCK : Mr. Maddock has raised a question that is really outside the scope of this paper inasmuch that it deals with technique rather than production. In essence, he has raised the question as to whether ratefixing before the event can be correct. As a general answer I would say that this depends on the ratefixer's knowledge on previous work of the same description. I have had no actual experience of putting work into a separate department to try it out and if I did so at any time I should be suspicious of the times that were made in such a department. We have to recollect that in the overall times which we shall allow for a given job it is very rarely that the machine element of the time exceeds one-half the total time allowed. It is fairly easy to ratefix for machine work. We know the speeds and feeds that can be used and, consequently, we know the actual cutting times, but when we come to consider the overall time we have to take into account all those various factors such as waiting for work ; waiting for tools ; setting-up times, and, most of all, handling times ; and whilst a close analysis will give us a fair figure for such times there is nothing, in my estimation, that will be so close as an actual time-study of the job under the conditions of manufacture that will obtain in the actual production of the bulk supplies.

If a works were large enough to have a trial department it would mean that they would have to have in such a department one machine of every type. They would, further, have to have skilled operators on those particular jobs. Now it is always the skill of the operator, or the lack of skill, that determines the overall time required. My own practice in the case of a new product is to put the work directly into the shop itself and to allocate for such work a pro tem. price as closely set as the conditions would permit, letting the operators all know that it is a pro tem. price, and a price which will, for a given period, give them a guaranteed wage, the period being of sufficient length of time to make a thorough study of the job. After this is done the real piecework price can then be allocated.

Mr. Gardner: Mr. Groocock, in referring to the fact that the ratefixer should have access to the estimates that have been made, seemed to infer that they should have this access so that they could perhaps, in dealing with their ratefixing, try to conform with the estimated cost. I fail to see how a ratefixer can, if ever, make any difference to his fixings. He has got to give a fair time. In my opinion, before the estimate is made, the ratefixer would have been consulted and also the tool designer, and I do not see that they could do anything afterwards or that the figures once given could ever alter the estimate.

Mr. Groocock: Mr. Gardner has brought in the case of the estimator. In the original paper I did not mention the estimator because, in my view, he works mainly prior to the receipt of the order. Estimates are generally based on similar apparatus that has been made before, or, alternatively, the estimator himself has approached the ratefixer and got from him his view of what a certain collection of parts would cost to machine. From this knowledge he has then made up his estimate. The point I tried to bring out in the paper was this: that if the ratefixer has no knowledge of what the labour content was in the particular cost he is likely to put on a price which will leave us in debt, whereas if he had some knowledge of the labour content and raised the matter before finally fixing the price, then probably the original estimated labour content could be met by the provision of some special tool, shall we say, such as a multiple set-up for the lathe. When you are likely to exceed the labour content the sooner you know it the better, because if you know this as a fact soon enough you can take steps to see that some action is taken to reduce the probable deficiency on the labour side.

Mr. Shuster: The lecturer mentioned a pro tem. price and giving it a run to see how it worked, and adjusting it at a later period. If you did such a thing would you not be running up against the

agreement between the Unions and the Employers' Federation, namely, that you cannot alter the price without altering the method ?

Mr. Groocock : In arranging for a pro tem. price you would not be breaking the agreement mentioned by Mr. Shuster, because there would be, or should be, a clear understanding between you and your workpeople that it was a pro tem. price. You can, if you wish, under the agreement mentioned, put men on day-work and run them for a sufficient length of time on day-work until you have had an opportunity thoroughly to time-study the job. Personally, my own workpeople would much rather have a pro tem. price for a given length of time because under such an arrangement they do earn quite a fair amount over their day-work rates, whereas if they were on day-work they would merely have their hourly rate.

A Visitor : I would like to know how the ratefixer is going to determine when the maximum efficiency is being obtained. If the man knows that the rates are only pro tem. he can, of course, take his time about it. How is the ratefixer going to determine when the right moment arrives to adjust his rates ?

Mr. Groocock : The question of when a pro tem. price should be changed to a fixed price is one which calls, first, for the close observation of the ratefixer and then, afterwards, his stop watch in a time-study. A series of time-studies will soon demonstrate whether an operator is holding up on the job, or not. For instance, in time-studying a job one would divide it something like this : (1) Putting the work in the machine ; (2) taking a cut down one side ; (3) taking a cut down the reverse side and top ; (4) gauging the work ; (5) removing work from the machine.

Now a time-study of such a job taken over a series of articles would soon demonstrate that each one of these operations taken over, say, 10 pieces, was varying. Now supposing a similar time-study on the same job was made two or three days later one would again find the same sort of variation, but the man who was holding back would definitely have no recollection of where he held back before, and, consequently, when, say, three time-studies had been taken and an analysis made of the results one could take the fastest time for each of the five operations and say that that would be a fair time to fix, having full knowledge that the operator would, when he became skilful, be able to do each of them. Whilst the question of ratefixing does not, generally speaking, touch on the functions that I have been dealing with in the paper, it is another of those sides which really calls for close consideration by the production engineer himself. While he will not be doing the ratefixing, he must have full knowledge of their methods and their scope. Unless he has this knowledge he will never be quite certain as to his general results.

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